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THE PARLIA[illegible]T OF THE COMMONWEALTH OF AUSTRALIA.

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# SECOND ANNUAL REPORT

OF THE

# COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

FOR THE

## YEAR ENDING 30TH JUNE, 1950.

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COMMONWEALTH OF AUSTRALIA.

# Commonwealth Scientific and Industrial Research Organization.

## SECOND ANNUAL REPORT FOR THE YEAR ENDING 30TH JUNE, 1950.

## I. INTRODUCTORY.

### 1. GENERAL.

The Commonwealth Scientific and Industrial Research Organization was established on 19th May, 1949, when the *Science and Industry Research Act* 1949 was proclaimed. Under that Act the Organization took the place of the existing Council for Scientific and Industrial Research, which in turn had in 1926 taken the place of the former Institute of Science and Industry.

The powers and functions of the Organization are similar to those of the Council and include the initiation and carrying out of research in connexion with, or for the promotion of, primary and secondary industries in the Commonwealth or any territory of the Commonwealth, or in connexion with any matter referred to the Organization by the Minister; the training of research workers; the making of grants in aid of pure scientific research; the testing and standardization of scientific apparatus and instruments, and the carrying out of scientific investigations connected with standardization; the collection and dissemination of information relating to scientific and technical matters; the publication of scientific and technical reports and periodicals; and acting as a means of liaison with other countries in matters of scientific research.

### 2. EXECUTIVE.

During the past year Mr. D. A. Mountjoy completed his term of appointment as a part-time member of the Executive and Mr. A. B. Ritchie was appointed to fill the vacancy. Since gaining an honours degree in economics at the University of Cambridge, Mr. Ritchie has had extensive experience with Australian pastoral industry.

### 3. ADVISORY COUNCIL.

After some delay arising out of legal difficulties connected with the drafting of Regulations under the new Act, the Advisory Council of the Organization was appointed in March, 1950. The members of the former Council for Scientific and Industrial Research were appointed to the Advisory Council, which meets under the chairmanship of Sir David Rivett. A full list of members is given in Chapter XXXII.

### 4. STATE COMMITTEES.

Following the promulgation of Regulations under the new Act State Committees were formed in each of the States with membership substantially the same as the State Committees set up by C.S.I.R.

### 5. DEATH OF DR. A. E. V. RICHARDSON.

The retirement of Dr. A. E. V. Richardson from the post of Chief Executive Officer was mentioned in the last Annual Report. Dr. Richardson's death occurred shortly after his retirement and the Organization and Australian science in general thereby suffered a severe loss. Dr. Richardson was connected with C.S.I.R. from its earliest days, first as a member of the Executive Committee, later as Deputy Chief Executive Officer, and finally as Chief Executive Officer. He played a major part in the development of the Council's work for the plant and animal industries.

### 6. ELECTION TO THE ROYAL SOCIETY.

An officer of the Organization, Dr. D. F. Martyn, has recently been honoured by election to the Fellowship of the Royal Society of London. Dr. Martyn, the Senior Officer of the Radio Research Board, who is located at the Commonwealth Observatory at Mount Stromlo, has gained an international reputation for his studies in extraterrestrial physics.

### 7. DIVISION OF BUILDING RESEARCH.

The status of the Building Research Section, in view of its growth and increasing responsibilities, has been raised to that of a Division. Mr. I. Langlands, who has been Officer in charge of the Section since its inception, became Chief of the new Division.

### 8. APPOINTMENTS OF CHIEFS OF DIVISIONS.

Dr. W. Boas, a world authority on metal physics and crystal plasticity, has been appointed Chief of the Division of Tribophysics in succession to Dr. S. H. Bastow, who was appointed to the Executive.

Mr. F. J. Lehany has been appointed Chief of the Division of Electrotechnology, filling the vacancy caused by the resignation of Dr. D. M. Myers on his appointment as Professor of Electrical Engineering, University of Sydney.

### 9. DEVELOPMENT OF NORTHERN AUSTRALIA.

During the year the North Australia Survey Party commenced a survey of the Ord-Victoria River region, in the north-west of Western Australia. The report on the reconnaissance survey of the Barkly Tableland region is now being prepared.

In the previous report reference was made to cooperative investigations with the Queensland Department of Agriculture and Stock on the Burdekin River. A grazing trial using several species of grasses and legumes was commenced near Ayr late in 1949. The pastures are irrigated and are being grazed with beef cattle. Tobacco investigations are being continued at Clare, near Ayr; particular attention is being paid to irrigation problems associated with growing tobacco on the soils of the Burdekin Valley. The detailed soil survey of the Burdekin Valley was continued and will be virtually completed by the end of the winter of 1950.

Late in the year, a research officer was secured for the Kimberley Research Station near Wyndham, Western Australia. The investigations at Katherine, Northern Territory, are being developed and a number of trials established under dry-land conditions. Special attention is being paid, too, to the possibilities of growing tobacco at Katherine under irrigation; the problems of growing cotton, peanuts, and other crops are being further explored.

It has not yet been possible to find properties suitable for the research on cattle pastures and cattle breeding that is to be done in Queensland. In the meantime, however, steps are being taken to develop basic laboratory facilities.

### 10. EXTERNAL TERRITORIES.

Under the new Act, the Organization is charged with responsibility for research of interest to primary and secondary industries not only of the Commonwealth, but also of Australia's external territories. During the year the Organization's officers have, when requested, provided technical advice to the Administration of Papua-New Guinea, and the Chief of the Division of Forest Products has been appointed to the Committee to report on the pine standards in the Bulolo Valley. The Division of Fisheries continued to co-operate in a survey of fisheries resources of the Territory.

### 11. Wool Production and Textile Research.

The major activities associated with the programme of biological research in the field of wool production are reported in Chapter VII. This work is carried out mainly in the Divisions of Animal Health and Production, Biochemistry and General Nutrition, and Plant Industry.

Research on wool textiles is reviewed in Chapter XV. During the year there has been a major re-organization of the work in this field. It has proved impossible to appoint a suitable leader to take charge of the whole wool textile programme, and accordingly three separate laboratories are being established, the co-ordination and general oversight of the research programme being in the hands of a Wool Textile Research Committee consisting of the Officers in charge of these laboratories.

The laboratory in Melbourne, which is under the direction of Dr. F. G. Lennox, will confine itself to chemical and biochemical problems, and most of its work will be of a fundamental, long-range nature. Staff for the laboratory has been provided by transfer of the staff of the former Biochemistry Section of the Division of Industrial Chemistry. A property in Royal-parade, Melbourne, near the University, has been purchased and is at present being converted to laboratories to form the head-quarters of the work.

Mr. V. D. Burgmann has been appointed Officer in charge of the Physics and Engineering Unit, which will be located in Sydney. Its work will be concerned with fundamental studies of physics of wool and of wool processing.

The third laboratory, of which Dr. M. Lipson is Officer in charge, is at Geelong and will be concerned with problems of more immediate interest to the textile industry, with which it will work in the closest collaboration. Temporary buildings for the staff of the laboratory have been occupied at Belmont, Geelong, where construction of the first unit of a permanent laboratory has been commenced. The work at Geelong is done in close association with the Textile College of the Gordon Institute of Technology, to the Council of which grateful acknowledgment is due from the Organization for its ready assistance in the provision of laboratory and office accommodation and for its general co-operation and interest.

### 12. Ninety-mile Plain.

The application of the results of the Organization's researches on minor element deficiencies in the Ninety-mile Plain region of South Australia is leading to the transformation into productivity of large areas of the 2,000,000 acres of country formerly considered worthless. Small amounts of zinc and copper applied with superphosphate enable the light sandy soils in this well-watered region to grow subterranean clover and other pasture plants as well as payable cereal crops. Considerable interest is being taken in the development of closer settlement schemes in this region.

### 13. Building Projects.

The Organization still faces great difficulties in developing its research programme owing to the lack of suitable buildings and the extreme slowness with which they can be provided. Many Divisions have to carry on their work under crowded and difficult conditions, and in many cases proposed new research programmes are held up through lack of accommodation. Among the major building projects contemplated are provision of a central block at Canberra to provide a library and other facilities for the Divisions of Plant Industry and Entomology and the Wool Biology Laboratory, Prospect, New South Wales. A start has been made on the Wool Textile Research Laboratory at Geelong and on the laboratory building for the Division of Tribophysics in the grounds of the University of Melbourne.

### 14. New Publications.

The Organization has established three new scientific periodicals: the *Australian Journal of Agricultural Research*, the *Australian Journal of Applied Science*, and the *Australian Journal of Marine and Freshwater Research*. The first of these is being published in collaboration with the Australian Institute of Agricultural Science and the Australian Veterinary Association. The Journals will be devoted to the publication of the results of original research and will be open to contributions from research workers irrespective of country or of the organization to which the authors are attached. Editorial Advisory Committees have been set up to assist in the selection of papers submitted for publication.

### 15. Overseas Conferences.

During the year a number of important scientific conferences were attended by officers of the C.S.I.R.O. These included the Fourteenth International Veterinary Congress, London; Twelfth International Dairy Congress, Stockholm; Fifth International Grassland Congress in Holland; International Union of Chemistry, Amsterdam; Inter-Congress of Wood Chemistry, Stockholm; World Forestry Conference, Helsinki; F.A.O. Conference on Mechanical Wood Technology, Geneva; First International Congress of Biochemistry, Cambridge; International Conference on Coal Preparation, Paris; Thirteenth International Beekeeping Congress, Amsterdam; Seed Certification Conference; Ninth International Congress of the International Seed Testing Association, Washington; Tenth Convention of Food Technologists, Chicago; African Regional Scientific Conference, Johannesburg; and a timber conference at Delat, Indo-China.

Dr. B. T. Dickson, Chief of the Division of Plant Industry, was a member of the Committee of Experts of the U.N.E.S.C.O. International Institute of the Arid Zone held in Paris in December, 1949. Dr. I. W. Wark, Chief of the Division of Industrial Chemistry, attended the Conference of the New Zealand and Royal Institutes of Chemistry in Auckland, New Zealand. Mr. T. C. Bell, Officer in charge of the Australian Scientific Liaison Office in Washington, was a representative at the United Nations Scientific Conference on the Conservation and Utilization of Resources at Lake Success, and also attended the U.N.E.S.C.O. International Technical Conference on the Protection of Nature. Dr. I. Clunies Ross, Chairman of the Executive, was appointed Chairman of the five-yearly Review Conference of the Commonwealth Agricultural Bureaux in London.

### 16. Technical Assistance to South-East Asia

As part of the general scheme for providing technical assistance to South-East Asia, the Organization has given hospitality in its laboratories to a few post-graduate students from China, India, and Malaya desiring further research experience in fields for which the Organization has special facilities. It is expected that increasing numbers of such visits will be made in the future.

### 17. Specialist Conference in Agriculture.

Arising from a recommendation of the British Commonwealth Scientific Official Conference in London in 1946, a conference of specialists was held in Australia from 22nd August to 15th September, 1949, to explore problems connected with the integration of the three main aspects of agricultural science—soils, plants, and animals. The conference had as its theme "Plant and Animal Nutrition in relation to Soil and Climatic Factors".

More than 100 scientific workers active in the fields of research covered by the conference met first in Adelaide to discuss some 70 contributed papers. Delegates then set out on a twelve-day tour through southern South Australia, Victoria, and southern New South Wales to see something of field aspects of Australian plant and animal problems. The concluding sessions, held in Canberra, reviewed the findings of the earlier sessions and made recommendations.

The Organization provided secretarial services for the arrangement and running of the Conference. It also published a handbook, "The Australian Environment", to give delegates a general picture of the history and present state of development of Australian plant and animal industries against the background of their environment. This book aroused such wide interest that a second edition has been printed for public reference.

### 18. Indo-Pacific Fisheries Council—Second Session.

The Organization collaborated with the Department of External Affairs and the Department of Commerce and Agriculture in making the necessary arrangements for the Second Session of the Indo-Pacific Fisheries Council of the United Nations, which was held in Sydney in April, 1950. Meetings were held at the Division of Fisheries, Cronulla, and Dr. Thompson, Chief of that Division, attended as Australian delegate.

A number of papers were submitted by officers of the Divisions of Food Preservation and Transport and of Fisheries. Contributions were also made to a handbook on Australian fisheries which was prepared for the conference. In addition, the Organization arranged excursions to give delegates an opportunity of visiting various Australian fisheries and of examining research which is being carried out in this field.

### 19. Studentships and Overseas Visits.

During the year under review, eighteen officers of the Organization were sent overseas for some months to collect information on new developments in scientific research and to acquire general experience in research and training in new techniques. In addition, seven studentships and one traineeship were awarded from general C.S.I.R.O. funds, six studentships for work on wool, and one from S.I.E.F. monies. The studentships are tenable for a period of two years, and at the close of the year 25 holders of studentships awarded in previous years were receiving training in the United Kingdom, the United States of America, Canada, and Australia.

### 20. Research Associations.

The Organization has continued to support the Australian Leather Research Association. This body, which has the legal form of a non-profit-making company registered under the New South Wales Companies Act, is similar to the research associations operating in Great Britain under the ægis of the Department of Scientific and Industrial Research.

### 21. Collaboration with Universities.

The Organization gratefully acknowledges its debt to the various Australian universities with which it works in close collaboration. The establishment of research units within the universities is of great importance as it enables the Organization's officers to enjoy the stimulus and help of authorities in different fields of science. The Organization's work in the various universities has now grown considerably and is mentioned in various places in the main body of the Report.

### 22. Science and Industry Endowment Fund.

The Executive of the Organization are the Trustees of the Science and Industry Endowment Fund established under the provisions of the *Science and Industry Endowment Act* 1926-1949. During the year, in addition to the granting of studentships for overseas training (*see* Section 19 above), the Trustees made grants to assist individual research workers as follows:—Dr. B. Breyer in connexion with polarographic investigations; Dr. E. B. Brown for the development of a new recording system for moving coil electric gauges; Mr. W. D. Francis for the preparation of an index to a new edition of "Australian Rain Forest Trees"; Miss Ursula McConnel for work on aboriginal mythology; Dr. B. J. Grieve and Dr. R. Patton for work on nectar flow in eucalypts; Mr. B. Shipway for work on the life history and distribution of the freshwater crayfish of southern Western Australia; Dr. J. Pearson for work on the comparative anatomy and embryology of marsupials; and to Mr. Tarlton Rayment for taxonomic work on bees. Assistance was also given to Mr. R. K. Morton and Mr. C. T. White in connexion with visits to overseas research institutions.

### 23. Finance.

Chapter XXXV. gives details of expenditure during 1949-50 by the Organization totalling £2,347,103. This amount includes a total of £380,242 derived other than direct from the Commonwealth Treasury, including £54,516 expended from the Wool Industry Fund and £241,277 expended on wool production and wool textile research from funds derived from the Wool Research Trust Account established under the provisions of the *Wool Use Promotion Act* 1945. Certain other expenditure involved in erection costs of buildings was also incurred on behalf of the Organization.

The Organization is particularly gratified by the way in which outside bodies continue to support it, and by the marked interest evinced by certain sections of industry which have provided donations for co-operative research. Among the many contributions received, reference may be made to those of the Commonwealth Bank, the Australian Dairy Produce Board, the New South Wales Department of Agriculture, the New South Wales Water Conservation and Irrigation Commission, the Cement and Concrete Manufacturers' Association, the Queensland Meat Industry Board, the National Gas Association, the Dried Fruits Control Board, the timber industry, and the pulp and paper industry.

A statement has been included of expenditure on contributions made by the Commonwealth to the Commonwealth Agricultural Bureaux, and the establishment and maintenance of the Chair of Aeronautics at the University of Sydney, and on grants to the Standards Association of Australia, the Australian National Research Council, and the National Association of Testing Authorities. The Organization is responsible for the administration of the funds expended in this way.

### 24. Organization.

For the purpose of carrying out its research work the Organization has established a number of Divisions and Sections. The Divisions, of which there are now sixteen, comprise the major establishments, which may be further subdivided into Sections; there are also independent Sections comprising establishments which have not reached a stage of development, so far as the scope and magnitude of their operations are concerned, to justify their designation as Divisions.

In the present Report an attempt has been made to group the material according to its subject matter rather than (as in the past) according to the Division or

Section concerned. Additional chapters and appropriate cross references have been inserted, however, to permit the work of any particular Division to be reviewed as a whole.

As the Organization's investigations extend on a Commonwealth-wide basis and as many of the investigations which are being conducted—particularly those concerned with problems affecting the agricultural and pastoral industries—necessitate experimental work in the field, a number of branch laboratories and field stations have been established in various parts of Australia.

The Head Office of the Organization is in Melbourne and associated with it are the Organization's Information Service, Central Library, and Central Experimental Workshops.

The Divisions which have been established (in order of their formation) are as follows:—

*Plant Industry,* with head-quarters and main laboratories at Canberra and field stations and experiment farms at Canberra, Australian Capital Territory; Ayr, Lawes, and Stanthorpe, Queensland; Trangie, New South Wales; Katherine, Northern Territory; and Kojonup and the Ord River, Western Australia.

*Entomology,* with main laboratories at Canberra and field stations at Bright, Victoria, and Trangie, New South Wales.

*Animal Health and Production,* with head-quarters in Melbourne and main laboratories in Melbourne and Sydney, a branch laboratory at Yeerongpilly, Queensland, and field stations at Badgery's Creek, New South Wales, Barooga, New South Wales, Cunnamulla, Queensland, and Werribee, Tooradin, Cobram, and Coleraine, Victoria.

*Biochemistry and General Nutrition,* with main laboratories at Adelaide and field stations at O'Halloran's Hill, Robe, and Brecon, South Australia.

*Soils,* with laboratories at Adelaide.

*Forest Products,* in Melbourne.

*Food Preservation and Transport,* with head-quarters and main laboratories at Sydney, branch laboratories in Brisbane, and minor laboratories at Gosford, New South Wales.

*Fisheries,* with main laboratories at Cronulla, New South Wales, an exploration section at Perth, and field stations at Brisbane, Thursday Island, and Hobart.

*Metrology, Physics, and Electrotechnology,* comprising together the National Standards Laboratory, Sydney.

*Radiophysics,* at Sydney.

*Industrial Chemistry,* with head-quarters and main laboratories in Melbourne.

*Tribophysics,* in Melbourne.

*Building Research,* in Melbourne.

The following are the Sections:—

*Irrigation Research Station (Murray Irrigation Areas),* Merbein, Victoria.

*Irrigation Research Station (Murrumbidgee Irrigation Areas),* Griffith, New South Wales.

*Radio Research Board,* with head-quarters in Sydney.

*Flax Research,* Melbourne.

*Ore Dressing Investigations,* Melbourne and Kalgoorlie, Western Australia.

*Mineragraphic Investigations,* Melbourne.

*Mathematical Statistics,* Adelaide.

*Dairy Research,* Melbourne.

*Meteorological Physics,* Melbourne.

*Coal Research,* Sydney.

*Wild Life Survey,* Canberra.

*Mathematical Instruments,* Sydney.

*Wool Textile Research Laboratories,* with headquarters in Melbourne and additional units in Sydney and Geelong, Victoria.

In addition, Regional Centres (co-operative research units staffed with officers from the appropriate specialist Divisions to attack the problems of a particular district) have been established as follows—

*Regional Pastoral Laboratory, Deniliquin,* with its associated Falkiner Memorial Field Station.

*Regional Pastoral Laboratory,* Armidale, with its associated field station, "Chiswick".

*Tasmanian Regional Laboratory,* Hobart.

*Western Australian Regional Laboratory,* Perth.

*Plant and Soils Laboratory,* Brisbane.

## II. SOILS.

### 1. General.

The Division of Soils is concerned, firstly, with the systematic mapping and study of Australian soils, a service of immediate value to the farmer and to the State advisory and administrative authorities; secondly, with special surveys of the soils both of areas marked out for future settlement and of already settled areas where problems in development have been encountered; and thirdly, with fundamental research on the pedology, chemistry, physics, and microbiology of Australian soils. On this third activity depends much of the applied research undertaken by other C.S.I.R.O. Divisions and outside authorities on problems affecting the primary industries.

Some work on soils and their behaviour under irrigation is being undertaken also at the Commonwealth Research Station at Merbein, Victoria, and the Irrigation Research Station at Griffith, New South Wales (*see* Chapter IV., Sections 2 (*a*) and (*b*) and 3 (*a*), (*b*), (*f*), (*g*)).

The work of the Division of Soils, which has its head-quarters at the Waite Agricultural Research Institute of the University of Adelaide, is described in the remainder of this Chapter.

For some time the soil survey activities of the Division have been decentralized, regional centres having been established at Canberra, Brisbane, Deniliquin, Hobart, and Perth. The subsequent development of regional laboratories is now relieving some of the pressure on the central soils laboratory at the Waite Agricultural Research Institute, Adelaide. Analytical work relating to soil surveys, and some of the general physical and chemical problems of the regions, are already being handled satisfactorily at regional laboratories. Thus a balanced research team has been developed at Brisbane, where work on soil survey, soil chemistry, and soil physics is in progress. Soils of the Burdekin Valley are being examined by this group.

Work is proceeding throughout the Commonwealth on the mapping of soils and the determination of their physical and chemical properties. The long-term objective is to obtain basic information on the soil resources of Australia, but a more immediate objective in some of the work in hand in all States is the assessment of areas proposed for land settlement. Co-operation with State and Commonwealth authorities has continued in this work. A soil school was run during the year at Deniliquin for officers of other Departments, especially in New South Wales, who were interested in obtaining a better understanding of soils and soil identification.

Soils are also being examined in the suburban areas of Melbourne and Adelaide to determine their behaviour in relation to house construction. A programme is in hand for identifying and locating soils which give trouble as foundation material, and for determining the behaviour of these soils with seasonal changes in water content. A mobile laboratory has been set up to assist in the examination of soils in the field. In all this work co-operation with the housing authorities in both cities has been maintained.

For some time the Division has been distributing cultures of *Rhizobium* for legume-seed inoculation on a commercial scale. The demand for these cultures by growers, however, has increased to such an extent as to impose a severe strain upon the Division's facilities. The University of Adelaide recently accepted responsibility for distributing these cultures to farmers but the Division of Soils will continue, at least for the present, to maintain the reference collection of the cultures which it has built up. In this and in many other ways close co-operation has been maintained with the Waite Agricultural Research Institute of the University of Adelaide, at which the head-quarters and central laboratories of the Division are located.

During the year four officers have been away making observations on work in progress in research laboratories overseas.

### 2. SOIL SURVEY AND PEDOLOGY SECTION.

Work in the Soil Survey and Pedology Section for the past year embraced both routine soil surveys and fundamental pedological investigations. In addition to the survey work, a system of mapping of Australian soils on a continent-wide scale was devised, as a basis for a future programme of work aimed at mapping the soils of Australia on a scale of about one in a million. Further, a start was made on compiling a manual of Australian soils designed to assist in identifying members of various Great Soil Groups as they occur in Australia. This manual is intended for use by officers of numerous authorities who are interested in soils for agricultural, forestry, engineering, and irrigation purposes.

(*a*) *South Australia.*—A further area on Kangaroo Island was covered by a routine survey, following two similar surveys in previous years, to provide information for the State authorities concerned with settling ex-servicemen on the central portion of the island. The soil pattern revealed was essentially the same as that found in the two previous surveys.

The soil survey of the Barossa district in South Australia which was begun last year was taken up again more intensively, and much progress has been made. The object of this survey is to study the pedological character of the soils, and also related problems of soil fertility, land-use, and erosion. The survey is continuing.

An examination has been made of the soils over a large area in the Kingston-Lucindale district, in the south-east of the State. This country is of considerable interest to land settlement authorities. It is a northerly extension of an area of similar and other soils upon which information has already been obtained by this Division. It includes large areas of shallow black soils which may require a rather extensive drainage system, and in general the geographical distribution and physical character of the soils are of the greatest importance in any development in that area. When the survey of this area is completed, work will be extended still further northward to embrace the soils of the Ninety-mile Plain, an area of poor solonized soils where much developmental work is already going on.

(*b*) *Victoria.*—Much field work was required to complete the survey of the Nathalia extension of the Murray Valley Irrigation Area. This work, which was begun in the previous year, is now finished and a report on the nature and distribution of the soils is being compiled. The area is in course of preparation as an irrigated settlement with part water right, and engineering developments are taking place.

(*c*) *New South Wales.*—As in previous years, the soils of the irrigated areas and of areas proposed for irrigation have been the most intensively studied. The soil survey of the Deniboota Irrigation District has been completed on a soil-association basis and a large portion covered in detail.

A preliminary visit was paid to the Jemalong Irrigation Area to assess the amount of work necessary for a comprehensive soil survey there, and to estimate the value of certain portions of the area for post-war land settlement.

The regional survey of the Riverina has continued, and the map showing the general distribution of the soils of this region is now taking shape. As a further result of this investigation it was concluded that the soils of the alluvial plains of the Riverina were laid down, not by the present streams of the area, but by a system of prior streams which traversed the area and predated the present stream system, which has a very recent history. A paper embodying this conclusion is being presented for publication.

Further north, in the Macquarie region (an area of some 30,000 square miles), a reconnaissance survey was completed. This survey shows the distribution of the soils of the region in terms of what are called "soil combinations", which are essentially patterns of representative soils of the Great Soil Groups. Two areas which may have a future as irrigation settlements were examined in more detail, and reports both on the general survey and on the two detailed surveys are being prepared.

In May and June a school of instruction in soils was held at Deniliquin. The object of this course was to provide means of identifying the soils which had been mapped and described in the numerous reports of this Section on the Riverina. A large number of officers of various State authorities are using these reports increasingly, and it has become necessary to acquaint them with the details of soil identification so that the most intensive and practical use of the maps and reports can be made, especially as these officers are largely concerned with the application of such data to existing and projected land-use activities.

Work on the Southern Tablelands region, particularly that close to the Australian Capital Territory, has been continued in a modest way, but this survey had to take place so that the Macquarie region survey could be completed. It will continue in the coming year.

The field work associated with the investigation of fertility decline in the soils of the Lismore district has been completed and the reports co-ordinating the survey and allied laboratory work are being prepared.

(*d*) *Queensland.*—The regional soils organization in Brisbane has now reached the stage where the soil survey projects of the region can be undertaken with the assurance that adequate chemical and physical investigations will run parallel to the field work. The Burdekin Valley soil survey, begun in the previous year, was advanced by a further programme of field work, largely of a reconnaissance character. As a result of the last two years' work about two-thirds of the soils of the Valley floor have now been surveyed, and a further year's work should complete the survey of the whole area. Despite a number of delays associated with field working conditions, steady progress has been made and an interim report prepared.

(*e*) *Western Australia.*—During the summer period, when practically all soil surveys in the south-west portion of the State are made, both reconnaissance and detailed surveys have been carried out. The reconnaissance work has extended our knowledge of the forested and scrub-covered soils of the region adjacent to Albany and radiating for some considerable distance therefrom, and has extended as far eastward as the Pallinup River. This work has followed the system, used in previous years, of making detailed spot surveys of limited areas so as to define the soil associations, and then linking them over much larger areas of country by wider-spaced traverses. A detailed soil survey and salinity investigation, aimed at defining the salt status of the soils, has been carried out on the recently acquired Glen Lossie Research Farm. This survey will provide the basic information for subsequent experimental work undertaken on this Station, and will permit the results to be extrapolated on to similar soils in the surrounding districts.

A preliminary reconnaissance, in the form of a soil-association survey, has been commenced on the coastal plain extending southward from Perth, which already embraces a number of small irrigation areas. The purpose of this study is to assist the State authorities in investigating further irrigation potential in the soils of this region. The association survey will permit a preliminary selection to be made of possibly suitable areas, which will then be examined in greater detail. Some months of further work will probably be required to complete the survey.

(*f*) *North Australia.*—The North Australia survey, which has been the joint responsibility of the Divisions of Plant Industry and of Soils, has continued the work commenced earlier on the Victoria River Downs country. This survey will link with the 1946 survey, which embraced the Darwin-Katherine region, and will also join the Ord River survey carried out by the Western Australian Department of Agriculture in 1944. This survey was made by means of the technique devised and used on the Darwin-Katherine and Barkly Tableland surveys. A further year's field work will be necessary for the completion of the Victoria River Downs survey.

(*g*) *Tasmania.*—The Tasmanian regional group was re-established, and a start made on a programme which as at present envisaged should occupy at least five years. This aims to complete work which had been commenced previously in two districts in Tasmania, and had to be left unfinished owing to staffing difficulties.

The first of these areas, in the Northern Midlands, has been the subject of further soil survey work and it is aimed to complete a unit of country embracing the soils of almost the entire Launceston Tertiary Basin. In this district a great deal of post-war land settlement is taking place, and information already supplied about various portions of the region has materially helped the land settlement authorities.

To assist the Tasmanian Department of Agriculture in their programme of intensive field experimental work, a number of detailed surveys of experimental farms have been undertaken for that authority. An inspection and part survey was also made on a small swamp in the Dip River district in north-west Tasmania, to help the land settlement authorities to decide whether it should be incorporated in an area being prepared for land settlement.

### 3. Soil Chemistry Section.

Investigations into seasonal trends in soil reaction at Barooga and the Waite Institute have been completed and written up for publication. At Barooga, seasonal effects were slight compared to the variations from spot to spot in the experimental areas. On Urrbrae loam at the Waite Institute, seasonal trends of the order of 0.15 pH unit were detectable although partly masked by the spatial variations which occurred even in small areas. In each season the pH of the soil increased after the opening rains in April and May; the pH value then slowly fell, to return to the original value in the succeeding dry season (January-April). It is probable that the change in soil reaction with time, even over a small area, is not uniform throughout the area, but varies from point to point in different directions and to different extents. In Urrbrae loam the spatial variation of the exchange capacity of the soil could be correlated with variations in clay and organic matter. A similar correlation could not be established at Barooga, but in one of the heavier soils at that locality differences in soil reaction could be associated with differences in exchangeable sodium.

The chemical examination of the red loam soils of Lismore, New South Wales, is nearing completion. Attention has been devoted to fractionation of the calcium, magnesium, sodium, and potassium in the surface horizons. The amounts present are mostly low. Generally more than half of the total calcium of the soil is present in an exchangeable form.

The factors controlling the availability of heavy metals in soils have continued to receive attention. During the year an officer returned from a period of study leave. While abroad he began investigations into the significance of organo-metallic complexes in soils in relation to the availability of manganese and copper. This work is being continued by laboratory studies and pot experiments.

Further progress has been made in developing spectrochemical techniques for analysing soil and plant material. Papers submitted for publication have dealt with improved methods of background correction and with the accuracy of spectrochemical determinations of molybdenum and copper in plants. A comparator-densitometer, specially designed for use with the complex spectrograms of soils, was constructed by the Division's workshop, and has been in use throughout most of the year. This instrument combines many features not available in commercially produced instruments and has been found well adapted for both routine and special measurements of density. Many elements of pedological or biological interest are present in soils at concentrations so low that they ordinarily escape detection. The possibility of concentrating as many as possible of these elements chemically in a single operation is being explored. Work is also in progress to determine the relationships between radiation emitted and concentration for elements regularly present in soils and plants at low to very low concentrations.

The air-acetylene flame method of spectrochemical analysis has been in routine use for determining exchangeable cations in soils throughout the year. The possibility of obtaining direct readings of the brightness of the spectral lines of all the exchangeable cations simultaneously, by means of phototubes mounted on the spectrograph, is being investigated. Such a method would not only shorten the procedure but would eliminate the errors associated with the photographic plate. With the co-operation of the Physics Department of the University of Adelaide a suitable amplifier has been built and other equipment is being assembled.

The air-acetylene flame spectrograph permits several different elements to be determined simultaneously in one small sample of material. Because of its unique suitability for the purpose, a local medical investigator requested the Division to carry out several analyses of blood plasma for him with this equipment, in connexion with his researches into Pink Disease. These analyses enabled him to establish the previously unsuspected part played by a subnormal sodium concentration in the blood serum, and led to a simple and effective cure for the disease.

The Section has continued to be interested in improving methods used for routine analysis of the type soils collected during soil surveys. Approximately 1,500 such soils have been examined during the year. Further work is being done on the plummet method for the rapid mechanical analysis of soils, the micro-determination of silica, iron, and alumina in clays, and the determination of free iron oxide in soils.

Most of the equipment for the regional laboratories at Perth and Hobart has now come to hand and these laboratories have functioned throughout the year. A regional laboratory was established and staffed in the former Chemistry Department of the University of Queensland during January, and this laboratory is now making the chemical investigations in connexion with all soil surveys in Queensland. An interest in chemical problems associated with the fertility of Queensland soils is also developing.

### 4. Soil Physics and Mechanics Section.

(*a*) *Water Entry into Soil.*—The physical properties of the soils of the Lower Burdekin Valley, North Queensland, are being investigated in connexion with the soil-survey programme proceeding in that area. A series of infiltration measurements has been undertaken on various soil types, to aid in assessing their suitability for development under irrigation. This work is to be extended and other physical properties of the soils are to be examined.

A number of projects dealing with the entry of water into soil have been concluded during the year. These include fundamental work on the downward flow of water into soil, on which a paper was published. Tension of soil water was measured during the application of water to the surface, and subsequently during drainage into dry uniform soil. It was found that in the wetter soil, tensions ranged between 4 and 18 cm. in different soils during watering. During subsequent drainage a tension gradient opposing downward flow was observed. Mean values of tension in the wetted soil ranged between 35 and 90 cm. in the different soils at a stage in the laboratory corresponding to field capacity. Field trials had earlier given similar results under less controlled conditions. A study of the effect of lateral movement of water on the infiltration data obtained from small infiltrometer plots has also been completed and this material has been prepared for publication. A further paper, dealing with the effect of cultivation practices on the infiltration of water into certain horticultural soils was published, and the project is now concluded. It was found that little change had occurred in infiltration characteristics of sandy soils at Berri, South Australia.

(*b*) *Effect of Thermal Gradient on Water Movement.*—Experiments have been conducted to determine the magnitude of water movements in soil due to temperature gradients. They have shown that large movements of water may occur where the pF of soil water exceeds 3.5, and these are consistent with movement in the vapour phase. Theoretical considerations indicate that equilibrium water contents under a temperature gradient are such as to give approximately constant differential heat of wetting for soil water throughout the soil mass. As yet this has not been confirmed, owing to the difficulty of determining heat of wetting of soils.

(*c*) *Seasonal Changes in Water Content of Soils.*—A problem of some importance in roadway or airport design and in foundation engineering is the determination of the ultimate water content of the soil when water entry is prevented by the surface cover, and water removal by plant roots is not significant. To study this problem, moisture-measuring instruments have been placed under a number of small buildings in the suburban areas of Melbourne and Adelaide, and under a roadway pavement near Adelaide. In an attempt to estimate the importance of temperature in causing water movement under such conditions, a larger and more elaborate installation was placed under a building on the premises of the Building Research Division, C.S.I.R.O., at Highett, Victoria. Another large installation of moisture-sensitive and temperature-sensitive elements will be made under a main runway at the Essendon airport, where the uniformity of the soil and the large extent of the covered area provide ideal conditions for a study of water movement. This study will be undertaken in co-operation with the Department of Works and Housing.

In addition to trials on covered sites, measurements have been made of the seasonal fluctuations of water content in soils exposed to normal rainfall and evaporation and carrying normal grass cover. In Adelaide, where some of the work has been done in co-operation with the University of Adelaide, it has been found that at depths down to 6 feet the soil is annually dried down to the wilting percentage and wetted up to a tension of about 300 cm. Except near the surface, this corresponds to a relatively small change in water content. Information is available for twelve sites and is being prepared for publication.

(*d*) *Shrinkage and Swelling of Soils.*—As a first approach to a study of the mechanism of shrinkage and swelling in clay soils, apparatus has been developed to measure the volume changes which occur throughout the soil profile. Installations of this apparatus have been made on typical Melbourne and Adelaide soils, alongside the moisture and temperature installations mentioned above. Data from these instruments may be interpreted to reveal the relationship between volume change and water-content change, and between volume change and soil-moisture tension in the undisturbed soil.

The actual movements recorded within the various profiles are of practical significance in the design of building foundations. Vertical movements of two inches have been recorded at the soil surface on some soils at Adelaide. The vertical movement in this soil does not reach a low enough value for stability of the building until a depth of more than six feet is reached.

Records have been kept for a period of up to two years on most sites, and these data are now being prepared for publication.

(*e*) *Recognition and Characterization of Soils for Engineering Purposes.*—Within recent years the practice of mapping soils for enginering purposes has developed, the soil profile being used as the basic unit for recognition and characterization. Attention has been concentrated on two main areas—the suburbs of Melbourne and of Adelaide. In Melbourne, where a soil map has been prepared and most major soil types identified, work has proceeded on the measurement of the engineering and physical characteristics of each type. A mobile laboratory has been developed to permit adequate soil testing in the field. Studies have been made on each soil type at locations where the semi-permanent installations described above provide data on volume change, water-content change, and the corresponding tensions in the soil water. In addition, the shear strength and apparent density are being measured in relation to the moisture variable. These investigations are not yet complete.

Progress is being made with a similar programme in Adelaide. Most of the important soil types have been recognized, and their characteristics were measured at a time when the soil was desiccated to an extent comparable with a severe summer condition. Further determinations are to be made with the soil in a wet (winter) condition.

(*f*) *Soil Structure.*—A drop-shatter technique has been developed to study the mechanical stability of dry soil. The size distribution is obtained, after dropping soil from specified heights on to a hard surface, by means of a rotary sieve. This distribution has been found to conform with the Rosin-Rammler relation for the size distribution of shattered brittle solids. The breakage by this technique has been found to correspond to that obtained by the application of manual forces in a field-descriptive method used by the Division. It is expected that this new procedure will assist in the characterization of soils.

It is important for many agricultural purposes to know whether the aggregates of a soil are stable in the presence of water. Methods for measuring the water-stability of aggregates have been examined. The micro-aggregation (sedimentation) technique has been examined with particular attention to the time of preliminary shaking. An exponential relation was found between aggregation, as measured by this method, and time of shaking. As a result of this work the shaking time for routine work was reduced from twenty to five minutes.

Preliminary work was carried out, using the micro-aggregation technique, on the effects on aggregate breakdown of temperature, surface tension, and the pressure of the air inside the aggregates at the time of wetting. The latter effect was the only significant one, aggregate breakdown increasing with pressure up to four atmospheres.

The water stability at various initial water contents was investigated by a wet-sieving procedure. The pressure-membrane apparatus and saturated salt solutions giving a range of relative humidity were used to obtain the various initial water contents. In some of the clay soils investigated the stability varied widely within a range which is commonly referred to as air-dry.

A new mechanical wet-sieving procedure has been set up in place of that formerly used by the Division for routine work.

Pore size distribution was studied by measuring the water withdrawn with increasing water tension. It was found that the interpretation was difficult in soils of high clay content where the water withdrawn was a result of shrinkage as well as of pore drainage. The use of non-polar liquids to obtain the pore size distribution of air-dry aggregates was unsuccessful, owing to the low permeability of the cellophane membrane to these liquids.

A method for measuring the apparent density of soil aggregates by the use of non-polar liquids is being investigated. This method can be used with both wet and dry soils.

(*g*) *Soil Colloids.*—An X-ray diffraction study of soils of the red-brown earth group taken from the Adelaide area has been commenced. This work was undertaken to provide clay mineral data for the work on housing foundations, and also as introductory to a general survey of the soil colloids of red-brown earths. The Adelaide clays show very poor crystallinity, their main clay minerals being illite, kaolinite, and montmorillonite, with chlorite appearing in lower horizons as do quartz and calcite. The effects of iron on the X-ray patterns for these soils are not understood, and are also being investigated.

Work has begun on the development of an X-ray spectrograph for fluorescent analysis of certain elements in soils, particularly of the clay fractions. In the first stage, attention will be given to the rapid determination of elements of atomic numbers between 13 and 30 (Al to Zn) which are present in proportions of greater than 1 per cent. It is hoped that the work may be extended to trace-element determinations, particularly for elements not well suited to optical spectroscopy. Several fluorescent spectra of iron have already been obtained from powder clay samples, using a curved quartz crystal section.

### 5. SOIL MICROBIOLOGY SECTION.

The main studies centre about *Rhizobium*, the genus of bacteria responsible for the nodulation of leguminous plants. A type of culture collection of almost a hundred strains of various species has been built up, and is periodically checked for retention of ability to infect suitable host legumes. So far, investigations have not indicated any correlation between cultural characteristics and powers of infectivity, so that the ability of a certain strain to tolerate extremes of temperature, acidity, or alkalinity, is not necessarily ground for suspecting contamination with other non-nitrogen-fixing organisms such as *Agrobacterium radiobacter*.

The scope of the type culture collection has been extended from purely commercial and taxonomic types to embrace a range of strains isolated from legumes forming part of the native vegetation of southern Australia. In this way we hope to gain information on the taxonomy of the strains, the ability to cross-inoculate other host genera, and the ability of inoculated legumes to contribute to the nitrogen status of the soils. Isolations have been made from the following genera of the Leguminosae: *Lotus, Lupinus, Trifolium, Ulex, Cytisus, Dillwynia, Platylobium, Pultenaea, Lathyrus, Acacia, Kennedya, Hardenbergia*, and *Clianthus.*

The demand by growers for cultures of *Rhizobium* for seed inoculation on a commercial scale has steadily grown to more than 2,500 cultures a year, and has placed such a strain upon the facilities and equipment of the Soil Microbiology Section that it was decided to ask the University of Adelaide to take over this aspect of the work. From March of this year commercial cultures were prepared at the Waite Agricultural Research Institute by University staff. For the present, however, the Division of Soils is still undertaking the checking of purity and assessment of the nitrogen-fixing ability of strains used commercially. Greenhouse tests have been made upon a number of strains of *Rh. trifolii, Rh. meliloti, Rh. lupini, Rh. phaseoli*, and *Rh. leguminosarum*, to determine which strains are most productive and best suited for commercial distribution.

An investigation of techniques and methods suitable for the commercial distribution of viable bacterial cultures has led to a number of innovations in handling, packing, storing, and distributing the cultures, so that large numbers of cultures can be most efficiently handled with limited man-power and equipment.

The large-scale programmes for developing poorer soils by use of sown pastures have raised the question whether it is necessary to inoculate subterranean clover to establish an adequate stand in the first year. Field trials are being initiated at Parndana on Kangaroo Island, at Keith and Lucindale in south-eastern South Australia, and at the Waite Institute, to assess the need for inoculating the Bacchus Marsh variety and the ability of strains of known performance to compete with one another from a mixed inoculum.

Investigations which were commenced in 1947 into the establishment of *Rhizobium* in field soils, in competition with native strains already populating them, have now been concluded. The difficulty in identifying a nodule as having been formed by the inoculant was overcome by using serological tests. Isolates were tested with appropriate antisera, and the proportions of nodules formed by the inoculum and native strains respectively were thus determined.

The strains tested were found to be serologically stable, and in only a few cases were the reactions characteristic of an inoculant found in the isolates from control plots. Serological identification of organisms inoculated into and recovered from soil is new to soil microbiology, and has proved entirely satisfactory.

It was found that when a suitable strain was used, 50 per cent. or more of the nodules were produced by the inoculum, but the strains differed considerably in their ability to establish themselves in the field. These results were based on thirteen field experiments, four of which were continued over two years.

A survey was also made of the distribution of antigens among the population of clover *Rhizobium* in the control plots in different localities. Striking differences were found in the proportions of strains containing specific antigens in different localities, but there were no consistent differences between larger districts. To follow up the latter findings, isolations of *Rhizobium* from naturally-infected plants have been made from thirteen separate localities of South Australia. These will be tested serologically and the results compared with data from Great Britain. Strains isolated in New South Wales have been made available for testing.

Comprehensive experiments were made to find out whether adaptation occurs between local strains of red clover and the indigenous strains of nodule bacteria in districts where the clover strains are grown. Strains of bacteria, isolated from Great Britain and Sweden, were all tested for efficiency on each strain of plant. Significant evidence was found of local adaptation in Sweden.

## III. PLANTS.

### 1. GENERAL.

The importance of primary industries in Australia's economy has naturally placed considerable emphasis on investigations of plant problems. The Organization's work in this field is undertaken mainly by its Division of Plant Industry, which has head-quarters at Canberra and experimental farms and stations at a number of centres throughout the Commonwealth.

Work on the special local problems of irrigation districts is undertaken at the independent Commonwealth Research Station (Murray Irrigation Areas) at Merbein, Victoria, and the Irrigation Research Station (Murrumbidgee Irrigation Areas) at Griffith, New South Wales (*see* Chapter IV.).

The Division of Entomology is carrying out work on weed control, insect pests of pastures and crops, and insect vectors of virus diseases (*see* Chapter IX.).

*Division of Plant Industry.*—The remainder of this chapter outlines the work in progress within this Division.

Unfortunately the lack of sufficient laboratory accommodation at Canberra continues to be an acute problem and a decided handicap to the work.

Tobacco trials conducted in association with the Queensland Department of Agriculture and Stock in the Ayr district continue to be promising, the yields both as to quality and quantity being very satisfactory.

During the year the Division of Plant Industry organized a Conference on Seed Certification at Melbourne in March, 1950, at which State officers responsible for the methods used in seed certification pooled their experiences and agreed to aim at practical uniformity such as has been achieved in seed testing methods and standards.

### 2. PASTURE INVESTIGATIONS.

The general programme of work on pastures continued on the basis presented in the Organization's Annual Report for the year ended 30th June, 1949. The work is closely related with that on weeds and plant introduction.

The Division of Entomology is responsible for investigating pasture pests, as noted in Chapter IX., Sections 8 and 9.

### 3. PASTURE INVESTIGATIONS AT CANBERRA.

(*a*) *Studies with Sown Pastures.*—Swards of Wimmera ryegrass and subterranean clover under commercial conditions commonly show a marked decline in vigour and yield of the ryegrass. Surface cultivation is frequently adopted as an attempted means of giving renewed vigour of growth to deteriorated swards, but experiments at the Dickson Experiment Station have shown that little improvement is effected by surface cultivation either before or after the commencement of growth. Where grass yields have been increased, there has been a reduction in total yield due to depression of the associate clover. It has been shown that vigorous development of this pasture depends on satisfactory levels of both phosphorus and nitrogen. Further work has now demonstrated that adequate superphosphate dressings alone, though giving heavy clover dominance in the first two or three years, subsequently gave a rapid increase in growth of grass and resulted in a vigorous balanced sward of high yield. The common belief that clover dominance can be checked by reduced superphosphate application is directly contrary to the facts. The effective means of overcoming clover dominance and maintaining grass is to continue with high phosphate dressings and thereby increase nitrogen status and grass development. The interval since cultivation is not critical in the maintenance of Wimmera ryegrass.

Three systems of grazing management are being compared on a phalaris-subterranean clover pasture. The aim is to determine whether there is any advantage in setting aside special paddocks for autumn and winter grazing, and spelling the remainder of the paddocks during these periods of early or slow growth. In the very favourable 1949-50 season no significant differences were recorded.

A comparison is being made of various row spacings on the yield of herbage and seed of phalaris and lucerne respectively. Each species has been sown in 7-in., 21-in., and 35-in. spacings at two rates of seeding. Competition effects on weeds, root distribution, and soil-moisture relationships are being studied.

The standard permanent pasture mixture in use at the Dickson Station is of phalaris and subterranean clover. While highly productive, this mixture of Mediterranean species fails to exploit fully the summer rainfall of this environment. The addition of other species to the standard mixture might give better distribution of growth throughout the year. Species being examined for this purpose include the annual and perennial bromes, *Festuca mairei, Poa iridifolia, Agropyrum cristatum, Phalaris arundinacea,* and *P. aquatica.*

Detailed studies are in progress of the annual species and strains of *Medicago*. In much of the Australian wheat belt, subterranean clover cannot be grown successfully and there is need for a suitable legume for short-term pastures. The annual medics provide very promising material for this purpose. The species or strains sought are those capable of vigorous growth in the environment indicated and free from "burrs" likely to infest wool, or likely to be eaten to exhaustion by sheep in the summer months. Initial examination of material from overseas is done at the Dickson Experiment Station. A number of promising types is under test in grazed swards at Wagga and Temora, in cooperation with the New South Wales Department of Agriculture.

(*b*) *Soil Fertility Studies.*—A series of long-term trials on the relationship of pasture and cropping practice to soil fertility trends, and especially on the factors involved in such changes in fertility, is being initiated at the Dickson Experiment Station. The first of these is concerned in particular with the rate of fertility lift, as measured by chemical, physical, and crop yield criteria, of a volunteer pasture, a self-regenerating annual leguminous pasture (subterranean clover) and a perennial pasture (phalaris-subterranean clover). Results from this class of work will not be significant for several years.

The significance of the return of animal excreta on the nitrogen cycle and fertility status of pastures is being examined. This involves the use of equipment on the grazing sheep to collect the urine and faeces, following the general technique developed for similar studies by the Department of Scientific and Industrial Research in New Zealand.

(*c*) *Plant Nutrition Investigations.*—Studies on the nutrition of pastures on the Southern Tablelands of New South Wales have been continued.

Work with superphosphate has shown that the effectiveness of this fertilizer on soils of very different origin is due as much to the sulphur it contains as to the phosphorus. Neither element alone is effective. Thus phosphatic fertilizers such as triple superphosphate would be ineffective in the development of these soils. Sulphur is particularly needed for protein formation in the plants, and this has a marked influence on nitrogen fixation in the clover.

On many soils the calcium in superphosphate is also of importance in pasture development. Nodulation and nitrogen fixation in clover are seriously limited on extensive areas of poor, acid soils by both the acidity and the calcium deficiency. Clover treated only with superphosphate on these soils may die out completely. On less affected soils it may survive and, where molybdenum is not deficient, will develop into a productive pasture after a period of about four years, if adequate superphosphate has been applied. Where molybdenum is deficient, as it usually is on these very acid soils, the pasture remains poor unless molybdenum is applied. Rapid development of the pasture can be obtained by applying heavy dressings of lime at sowing. This treatment encourages nodulation by providing calcium and counteracting soil acidity, and stimulates nitrogen fixation and growth of clover by releasing molybdenum from the soil. The same results can be obtained at much lower cost by drilling the inoculated clover seed with 2 cwt. of lime per acre to stimulate nodulation, and applying molybdenum with the superphosphate. Excellent pasture can be grown on the acid soils in this way.

Studies on the residual effects of superphosphate on soils of the Southern Tablelands of New South Wales have shown that in the first four years of the pasture—the period during which this problem has been examined—the total yield of pasture obtained depends almost entirely upon the amount of superphosphate applied over the period.

The total yields obtained were the same whether the superphosphate was applied each year, in the first and third years only, in the first and fourth years, or where the whole of the four-year dressing was applied in the first year, provided the same total amount of superphosphate was applied in each case over the four years. The earlier application of the total dressing encouraged more rapid development of, and transition from, the clover-dominated phase, and earlier development of the grass component. The point of most significance in this work is that the cost of distributing superphosphate and the labour required could be considerably reduced by less frequent application of the fertilizer.

(*d*) *Vegetation and Pasture Survey.*—Most of the field work on the vegetation and pasture survey of the south-west slopes and adjacent plains of New South Wales has now been completed, and the material is being prepared for publication. Seven associations have been defined for the region, two of dry sclerophyll forest, three of woodland, the river red gum association, and the savannah association of disclimax *Chloris-Danthonia*. The distribution of each of these associations throughout the region has been defined and is being mapped. The pasture types developing on clearing or under the influence of grazing in each of the associations are under study.

(*e*) *Toxaemic Jaundice Investigations.*—Co-operative work with the Division of Animal Health and Production has been continued (*see* Chapter VII., Section 15). The botanical composition of irrigated subterranean clover pastures at Cobram on which the disease is under study is being determined at monthly intervals.

(*f*) *Pasture Chemistry.*—The distribution of certain pasture species may be influenced by phosphate availability. Glasshouse experiments have been conducted to determine the relative availability of natural forms of soil phosphate to different plant species. Sand culture experiments indicate that phosphate adsorbed on clay was readily available to oats, subterranean clover (*Trifolium subterraneum*), burr medic (*Medicago sativa*), and long storksbill (*Erodium botrys*). Tricalcium phosphate was also readily available to *Erodium* but was not easily available to burr medic and still less available to subterranean clover and oats. *Erodium* also made some use of apatite, a form of phosphate completely unavailable to the other three species.

Samples have been collected in order to make a survey of the mineral composition of subterranean clover in New South Wales; a comparison of the mineral uptake of a number of varieties of subterranean clover is also being made.

Analyses of oats grown in a pot-culture experiment to determine the relationship of growth stage in oats to the manganese, copper, and molybdenum content of the plant material are almost completed. Preliminary examination of the results shows that the manganese content of the plant material remains more or less constant, throughout the whole period of growth, at a value probably determined by the manganese availability in the soil. There is a steady increase in the manganese content of the leaf material with a corresponding decrease in the manganese content of the stem material. The copper content of the plant falls steadily from a maximum at an early stage of growth until the flowering stage. The copper content of the leaf material is consistently greater than that of the stem material and both follow the same trend as that of the whole plant. Molybdenum increases to a maximum at a later stage of growth and then decreases as the plant approaches maturity. The molybdenum content of the stem material is greater than that of the leaf material. These patterns of mineral content in the various plant parts with advancing growth stage are distinct and characteristic for each element, and are maintained over a range of very diverse soil types.

### 4. PASTURE INVESTIGATIONS AT TRANGIE, NEW SOUTH WALES.

Principal dependence in this region is placed on the native pastures. Though a number of introduced species is being tested (*see* Section 12 (*b*)(ii)) the main emphasis in the programme at this centre is on the native swards.

An ecological survey of the vegetation and pastures of the district is nearing completion. Six hundred and eighty square miles have been mapped in an area bounded by Nevertire (west), the Macquarie River (north), Narromine (east), and an east-west line approximately twelve miles south of Trangie. The main features under investigation are—(i) distribution of six tree-shrub communities of the *Eucalyptus populifolia—Callitris glauca* association; (ii) distribution of pasture types in relation to light and heavy soils; and (iii) composition of the pastures in relation to intensity of grazing, a study which includes the measurement of basal cover of perennial grasses and the density and yield of annual species.

These studies have shown that a series of degenerative stages with increasing intensity of stocking can be recognized on each of the principal soil types. For example, on the heavy soils there is a dominance of Liverpool Plains grass (*Stipa aristiglumis*) with light rates of stocking. As stocking intensities increase, fairy grass (*Sporobolus caroli*) and corkscrew grass (*Stipa setacea*) successively become prominent components of the pasture. Finally, with severe grazing, the pasture is reduced to an almost pure stand of windmill grass (*Chloris truncata*). A similar degeneration, though involving a distinct series of species, can be recognized on the light soils.

A grazing trial is being conducted in co-operation with the New South Wales Department of Agriculture to determine the influence of stocking rate and of spring and autumn deferment on a *Stipa-Chloris* pasture, and on the live weight and wool production of Merino wethers. The second year of the trial has been characterized by above-average rainfall conditions, excepting a dry period of seven weeks during December-January. From March, 1949, average amounts of green feed available to the sheep at bimonthly intervals were as follows (yield of annuals in brackets):—9.42 (1.64), 9.18 (.87), 6.22 (1.22), 7.20 (2.32), 8.09 (.45), 1.32 (.04), and 19.45 (7.07) cwt./acre. The three rates of stocking have maintained significant differences between yields of green herbage at each sampling, particularly those of perennial grasses. Deferment of grazing for six weeks during autumn produced only a temporary improvement in available herbage, as compared with continuous grazing. The experimental plots were damaged to a small degree by rabbits for about five months of the year.

During the first year of the trial no significant change attributable to any of the grazing treatments was recorded for either density or percentage basal cover of the perennial grasses. The density and cover increased over the whole experiment as a result of the favorable seasonal conditions. At the end of the second year important differences have been shown in the case of basal cover. The basal cover of perennials improved under all treatments (mean 3.32 per cent.), but the degree of improvement was significantly greater with the lighter stocking rate (one sheep to two acres).

### 5. PASTURE INVESTIGATIONS AT REGIONAL PASTORAL LABORATORY, DENILIQUIN, NEW SOUTH WALES.

(*a*) *Natural Pastures*.—The ecological study of the influence of intensity of grazing on *Danthonia semiannularis* grassland has continued since May, 1949. The amount of pasture available has increased greatly in the ungrazed plots, increased slightly in the lightly grazed plots, and diminished by a small amount in the medium and heavily grazed plots, compared with the amount of forage present when the trial commenced. There has been no change in the "condition" of the pasture since May, 1949, and the species present at the commencement of the trial and those which normally occur with the climatic conditions experienced during 1949 have persisted.

Preliminary examination has been made of the structure and floristics of the *Atriplex vesicaria* association south of the Murrumbidgee River. The contribution made by annual legumes and herbs seems to be an important aspect for future study. A number of seral stages are apparent within the area, and it is intended to trace the stages of degeneration related to grazing practices.

A South European ruderale, *Scorzonera calcitrapifolia* Vahl, has been observed at a number of points near Deniliquin; this first record of its occurrence in Australia has been published.

(*b*) *Irrigated Pastures*.—Studies begun in 1949 to determine the factors involved in the emergence of pasture and forage species sown over a range of autumn and spring conditions and with various organic litter treatments, fungicide treatments, and the depths of sowing, have been completed. Preliminary examination of the record of surface soil temperature, moisture content, and consistence, and of brairding counts and yields, indicates that the most significant effects will be associated with species requirements and the differences between the two soils on which the trials were made. The litter treatments have resulted in higher soil-moisture content and lower soil-surface temperature, which seems to have slowed down the rate and total emergence during the colder months and to have increased them in the warmer months.

A trial with various nitrogenous fertilizers and with a range of minor elements on irrigated swards of subterranean clover and of Wimmera ryegrass gave no significant yield differences in the first year, though visual responses to nitrogen were apparent. On an irrigated Wimmera ryegrass-subclover pasture on the lighter soils, superphosphate in applications above 2 cwt./acre gave significant yield increases over dressings of ½ or 1 cwt. On the clay soils no response was obtained. These experiments are continuing.

Nitrogen (as blood manure at 1 cwt./acre), calcium (as slaked lime at 1 ton/acre), and phosphate (as superphosphate at 2 cwt./acre) were applied singly and in all combinations to an irrigated Wimmera ryegrass-subclover pasture in its first reseeding year, on a loam and on a clay soil. No significant fertilizer interactions were produced. On the loam soil, superphosphate and lime both increased clover yield and the nitrogenous fertilizer caused a decline in clover yield and increased ryegrass yield in the mixed sward. On the clay soil the response was to superphosphate, which increased the yield of both subclover and ryegrass.

The examination of visual deficiency symptoms of plants growing at the Falkiner Field Station indicates phosphorus as the major deficiency, together with nitrogen deficiency.

Trials of a number of *Vicia* and *Lathyrus* species have shown that under conditions of intermittent grazing *V. dasycarpa* produces a dense aggressive stand which regenerates well. *Bromus marginatus, B. unioloides, Lolium subulatum, Phalaris tuberosa* (G.B81), *P. minor* hybrid, and *Festuca pratensis* are worthy of further study as grasses which will produce well when grazed and given supplemental irrigation in autumn and spring. Among the subterranean clover strains, Bacchus Marsh and Clare were the best producers in autumn and early winter, while Tallarook and Bacchus Marsh were best in late winter and spring. The best summer-growing legumes under irrigation are *Melilotus alba, Medicago sativa* (especially Hairy Peruvian), *Trifolium repens* (Irrigation strain), and *Trifolium pratense* (Montgomery). Among the summer-irrigated grasses *Dactylis glomerata, Lolium perenne, Bromus unioloides, B. inermis,* and *B. marginatus* gave the best yields under grazing. After the November grazing *Phalaris tuberosa* made little growth when irrigated throughout the summer.

*Urochloa mozambicensis, U. pullulans, Setaria sphacelata,* and *Pennisetum* spp. are among summer-growing grasses which have shown promise for future soil amelioration work.

(*c*) *Irrigation and Soils Studies*.—A study on Cobram loam has shown that flood irrigation depressed infiltration capacity after cultivation and sowing to pasture. Soil changes brought about by imposing a pasture irrigation environment on two soils (a clay loam and a clay) are being followed. Changes in physical and chemical characteristics of the soils are being defined annually.

The relationship between flow rates and irrigation water applied in border ditch irrigation is being studied. A water-measuring unit has been designed and constructed to obtain more accurate measurement and better control over a wider range of flow rates.

Examination of irrigation records on the Falkiner Memorial Field Station has shown that the average consumption of irrigation water per irrigation (inclusive of seepage and drainage losses) was 3.1 inches in 1947-48 and 3.2 inches in 1948-49. Spring sowings used more water than autumn sowings. During the establishment year Wimmera ryegrass-subclover pasture produced most pasture per unit of irrigation water used. Second year production per water unit was highest with lucerne, followed by Wimmera ryegrass-subclover, phalaris-subclover, and summer-irrigated pastures in that order.

A survey of ten irrigation farms in the Berriquin and ten in the Wakool Irrigation District has been completed. Useful data have been obtained on the consumption of irrigation water, pasture development, methods of irrigation, type of production, and irrigation control.

(*d*) *Chemical Studies.*—Irrigation water from the Falkiner Memorial Field Station has been analysed and a review of criteria for determining the quality of irrigation water has been written. The quality of this water is good, with only a small amount of soluble salts and a favorable calcium-sodium ratio.

Considerable changes in total soluble salts, chloride, and pH resulted from two years' autumn-spring irrigation of the loam and clay soils at the Field Station. In the clay soil there has been a considerable leaching of salts (particularly chloride) from the first and second foot, and an accumulation in the third foot. As expected, pH has risen in the first two feet and remains almost unchanged at three feet. (Small amounts of calcium carbonate and gypsum are present in the third foot.) In the coarse-textured soil the concentration of salts remains low and little changed to one foot, and there is slight leaching in the second and third feet. With both soils the surface has been severely dispersed by irrigation.

### 6. PASTURE INVESTIGATIONS AT ARMIDALE, NEW SOUTH WALES.

(*a*) *Grazing Management Studies.*—Experiments involving comparisons of different rates of stocking and of continuous versus rotational grazing are being carried out on a typical natural pasture in co-operation with the Division of Animal Health and Production (*see* Chapter VII.). In these experiments a study is being made of the effects of different grazing treatments on—

(i) Infection by internal parasites.
(ii) Wool production.
(iii) Live weight, growth, and behaviour of sheep.
(iv) Yield and botanical composition of the pasture.
(v) Chemical composition of the pasture.

During the first years of the experiments the yield of the pasture was unaffected by grazing treatments, but the six months' data so far available for the second year indicate a slight but consistent reduction in yield under heavy grazing. The seasonal fluctuations in yield have been approximately the same under all grazing treatments, declining from about 20 cwt. per acre in the summer to about 12 cwt. in July. A peak in the yield curve, due to annual grasses, was recorded in early December of the second year, followed by a second and higher peak in March-April when the perennial grasses were at a maximum.

A third experiment has been commenced in which the effect on the yield of the pasture of different sizes of flock, each grazed at the rate of one sheep per acre, is being studied.

(*b*) *Species Trials.*—The testing of forage grasses and legumes is being conducted along two lines: (1) row trials, and (2) swards, with emphasis on winter production.

The rows of crimson clover, regenerating early from self-sown seed, produced heavily in winter. Lucerne has given a good year-round production, white clovers good spring production, and red clovers heavy summer production. Some strains of subterranean clover were promising. Two new strains of *Phalaris tuberosa*, Akaroa cocksfoot, several tall fescues, and sheep's burnet (*Poterium sanguisorba*) were highly productive. A number of Kansas strains of *Bromus inermis* have grown very well.

In a two-year-old subterranean clover variety trial, carrying five sheep per acre through the winter, Tallarook out yielded three other strains in September and November. It also set much more seed. Small sward trials of 20 grasses and 20 clovers have been in progress for one year. A pasture species trial at Bundarra on granite showed excellent results with rye grasses in the first year, but these may not be maintained. Phalaris and red and white clover were excellent. Lucerne is improving in the second year.

(*c*) *Fertilizer Trials.*—A trial with copper, boron, molybdenum, and zinc was commenced in 1947 on a sown pasture (*Phalaris tuberosa*, subterranean clover, and red clover) on granitic soil. All plots received a basal dressing of superphosphate. Superimposed on the fertilizer treatments were pH treatments involving the use of lime and sulphur. In the first season no marked differences in yield were recorded from any treatment. In the second season the yield of clover was not influenced by lime but was reduced from 26.8 to 16.7 cwt. per acre where sulphur had been applied. The soil pH at the time of sampling in the second season was 7.5 with lime, 6.1 without fertilizer, and 5.3 with sulphur. Interactions between pH and minor elements were recorded and these are being studied further.

A trial of varying rates of superphosphate on *Phalaris tuberosa*, red clover, and subterranean clover pasture, after carrying five sheep to the acre through the winter, gave increases of 100 to nearly 400 per cent. in clover yields with increases of fertilizer. Strong evidence of the benefit of the clover to the grass has now appeared. In a pasture trial at Bundarra 2 cwt. of superphosphate more than doubled the yield of legumes and phalaris by October. The estimated increase in yield of phalaris at maturity due to superphosphate was of the order of 400 per cent.

In a fertilizer trial on basalt soil involving phosphorus, sulphur, nitrogen, and superphosphate, highly significant increases in yields of clover with sulphur alone and in combination were obtained six weeks after application. Increases were of the order of 150 per cent. On granite soil at Cherry Hill highly significant increases of 100 per cent. were obtained by the use of sulphur alone on clover.

(*d*) *Pasture Establishment Studies.*—In the trial on methods of sowing *Phalaris tuberosa*, red clover, and white clover, by normal drilling, broadcasting, cross drilling, and alternate 7-in. rows of grass and clover, spring yields were greatest on the normal and cross-drilled plots. Differences in botanical composition are appearing.

(*e*) *Improvement of Natural Pastures.*—Experiments to test the effectiveness of different methods of sowing clovers into natural pasture are being carried out at a number of centres. Sowing with a combine or disk drill resulted in a threefold to sixfold greater establishment of clover than broadcast sowing.

The value of pelleted and unthreshed subterranean clover seed for sowing into natural pasture is being investigated.

(*f*) *Grazing Trial on Granite.*—At Cherry Hill, row lucerne grazed at five sheep per acre and *Phalaris tuberosa*—subterranean clover pasture at three sheep per acre gave big increases in body weight over the winter period. Wimmera ryegrass and oats respectively at five sheep per acre each only maintained body weight. Sheep on natural pasture declined in body weight when the rate was only eight sheep to 10 acres.

### 7. PASTURE INVESTIGATIONS IN WESTERN AUSTRALIA.

(*a*) *Grazing Management Trial.*—A comparison of continuous and autumn-deferred grazing with Merino wether sheep on a sown annual pasture of Wimmera ryegrass, sand brome grass (*Bromus arenarius*), and Dwalganup subterranean clover was commenced at Perth in May, 1949. The pasture is stocked at 2.67 sheep per acre. Owing to extremely poor growth during the winter months of 1950 all sheep were removed from the experiment for nine weeks (26th September to 28th November). Apart from this break, the sheep have been maintained satisfactorily, those on the deferred treatment being consistently higher in body weight. The most striking feature to date is the difference in botanical composition resulting from grazing treatments; the continuously grazed pasture is dominated by Wimmera ryegrass, and the autumn-deferred pasture by the volunteer brome—*Bromus gussonii.*

(*b*) *Species Investigations.*—(i) *Wimmera ryegrass.*—Studies on the extra-grazing factors responsible for the retrogression of Wimmera ryegrass in sown pastures are nearing completion. An experiment conducted at Glen Lossie Field Station, Kojonup, during 1949 provides evidence that (1) growth responses to surface cultivation, whenever they occur, are due essentially to higher seedling establishment rates, and (2) deep cultivation in the autumn, either before or after the opening rains, stimulates growth of the ryegrass plant through increased nitrogen supply.

(ii) *Phalaris tuberosa.*—An experiment designed to compare the effects of normal 7-in. row spacing and wide spacing (up to 49-in.), both with and without inter-row cultivation, on the persistency and yield of *Phalaris tuberosa,* was commenced at Glen Lossie, Kojonup, in 1949.

(iii) *Subterranean clover.*—Some 70 strains of this species were grown in spaced rows at Glen Lossie during 1949. A number of promising strains have been selected for further work both in rows and swards.

(*c*) *Nutrition Studies.*—The effects of superphosphate on the growth of Dwalganup subterranean clover on Kojonup gravelly sand are being examined. Experiments initiated in 1949 indicate that where the soil is acutely deficient in phosphorus yield increases in the first year are slight with applications of beyond 2 cwt./acre superphosphate. Residual effects will be determined. Experiments with zinc on this soil and on a similar soil at Narrogin showed increases of 20–30 per cent. in the yield of subterranean clover at mid-August, but no effect at the end of October. Significant effects of zinc on *Erodium,* an associated volunteer species, were observed at Narrogin.

A field trial on Crawley sand at Perth with three strains of subterranean clover (Dwalganup, Bacchus Marsh, and Mount Barker) indicated closely comparable strain responses to potassium. At the beginning of September, applied potassium resulted in a 26 per cent. increase in yield; by mid-October the figure had risen to 46 per cent. Pot-culture trials with five strains of subterranean clover on the same soil type confirmed the similarity in growth response to this nutrient.

Further studies on the growth of subterranean clover on Muchea sand have confirmed the toxic effects of phosphorus at levels equivalent to 2 cwt./acre superphosphate, provided that the phosphorus is applied in water-soluble form, and also that neither lime nor combined nitrogen is applied. Much higher levels (equivalent to 6–9 cwt./acre superphosphate) are required to produce comparable effects on the yellow subsoil sand of the Crawley sand soil type. Further experiments on the factors relating to this toxicity problem are in progress.

(*d*) *Pasture Investigations Relating to the Sheep Infertility Problem.*—The three exploratory grazing trials at Narrogin, Wandering, and Kojonup were discontinued after the 1949 lambing, owing to the failure to maintain clover dominance in the "control" pastures. No serious infertility problem arose in any of the experimental flocks throughout the duration of these trials.

The results of bioassay, by the Division of Animal Health and Production, of Dwalganup subterranean clover grown at Glen Lossie, revealed that plants adequately supplied with superphosphate were significantly lower in potency than phosphorus-deficient plants (i.e., those not supplied with superphosphate); no other nutrients produced significant effects on potency. This phase of the investigations is being continued to determine whether phosphorus alone is responsible for the effects observed, and whether other factors affecting growth-rate of the plant can produce potency differences. The work is being done in a co-operative programme with the Division of Animal Health and Production.

(*e*) *Grazing and Rotation Trial.*—Following the three-year pasture phase of the trial at Wongan Hills, the entire experimental area was sown to wheat in 1949. The cereal data showed that both vegetative and grain yields were very much lower on areas sown to grazing oats during the pasture phase than where volunteer pasture (capeweed) had constituted the pasture phase. The crop following Wimmera ryegrass-subterranean clover gave the highest yields. This investigation is a co-operative project with the State Department of Agriculture and the University of Western Australia.

### 8. PASTURE INVESTIGATIONS AT CUNNAMULLA, QUEENSLAND.

(*a*) *Grazing Management Studies.*—An experiment comparing the effect of light, medium, and heavy rates of stocking on Mitchell grass, under both continuous and rotational grazing, has been continued. With the exceptionally favorable conditions of the past four seasons no significant differences in the yield of the pasture or the live weight of the sheep have been recorded, though there has been a tendency for live weights to be higher with heavier stocking. This indicates that with light stocking the pasture has been under-grazed, with the result that the perennial grasses have become too rank and have reduced the important herbage species. Wool weights and the value per pound have been approximately the same irrespective of grazing treatment.

(*b*) *Pasture Regeneration Studies.*—In this experiment an attempt is being made, by conservative stocking of a Mitchell grass pasture, to regenerate the perennial species which had previously been reduced by drought. An improvement in the density of Mitchell grass has been recorded. Seasonal conditions appear to have been more important than stocking treatment in effecting this improvement, although slightly better results have been obtained where the paddocks are spelled during the period of the pasture's active summer growth.

(*c*) *Field and Floristic Studies.*—Type sites have been established on a number of pasture types in the Cunnamulla-St. George-Dirranbandi area. Samplings are made at intervals, usually after rains, to obtain data on the seasonal and botanical composition of the pastures.

(*d*) *Limebush* (Eremocitrus glauca) *Life History Studies.*—Observations have been made annually since 1943 on the rate of increase in numbers of plants in limebush thickets. During this period the overall increase has been only 21 per cent. In view of the rapid spread of limebush in areas east of Cunnamulla it would appear that the location of these observations is near the western limit of this species and therefore not well placed for a study of limebush encroachment.

## 9. Pasture Investigations at Lawes, Queensland.

(*a*) *Natural Pastures.*—Experiments near Gladstone, designed to give basic information on natural spear grass (*Heteropogon contortus*) pasture, have shown that the period of pasture growth is controlled by the incidence of summer rainfall. Winter rain has little effect. There is some evidence that severe defoliation (whether by cutting or burning) has a depressing effect on subsequent yields. *Heteropogon contortus* is the main species of this pasture and at times constitutes up to 80 per cent. of the total dry matter. Very few other plants are present in any quantity. Chemical analyses show that protein is deficient for a considerable portion of the year and there is a suggestion that phosphorous also may be deficient at certain times. Selective grazing, and the presence of small areas of green feed along watercourses, have an appreciable effect in offsetting the low nutrient level in the main area of pasture.

Experiments at "Rodds Bay" have shown that the legume Townsville lucerne (*Stylosanthes sundaica*) can be incorporated into natural spear grass pasture by surface seeding. With applications of superphosphate, yields have averaged 5 cwt./acre, without any reduction in grass yield. There is some evidence that grazing is necessary to the establishment and maintenance of this plant. *Stylosanthes gracilis* also has made good growth, with yields exceeding those from *Stylosanthes sundaica,* but the frost susceptibility of this species would limit its use.

An experimental area of approximately 250 acres has been sown to Townsville lucerne with a view to evaluating this plant against untreated natural pasture, under near-commercial grazing conditions and in relation to economic returns.

An experiment to determine the influence of burning on the botanical composition of natural pastures at Lawes has shown that *Heteropogon contortus* is favoured by burning; the old plants are resistant and fire promotes germination of seed. It is suggested that typical spear grass pastures may have resulted from regular burning in the past. Approximately 12–18 lb. of nitrogen per acre may be lost when the dry pasture is burnt, compared with an estimated loss through the grazing animal of less than 1 lb. of nitrogen per animal.

(*b*) *Sown Pastures.*—(i) *Rhodes Grass.*—An experiment designed to assess the relative value of two varieties of Rhodes grass and to evaluate lucerne as a component of Rhodes grass pastures has yielded valuable information. Grazing has been at an intensity of one beast to 1¼ acres. There were negligible differences in stock maintained on the two grasses, but the addition of lucerne to either grass gave much better summer grazing and better live weight gains. There was little improvement during winter months. Rhodes grass, grown in association with lucerne, significantly outyielded that grown alone, the difference amounting to 4–10 cwt./acre.

The differences in animal response were well defined. The experiment has now been modified to allow more detailed study of the effect of lucerne on the growth and vigour of Rhodes grass.

(ii) *Row-cultivated Pastures.*—In lucerne pastures under row cultivation, the vigour of individual plants was enhanced, but there were no significant differences in the mean annual yield from swards and from rows at 42-in. and 63-in. spacing. The yield per unit of row length was, in all cases, proportional to the number of rows per acre. In swards, progressive yields (i.e., at intervals of eight weeks) reflected the incidence of rainfall, whereas under row cultivation there was an appreciable advantage from the better regrowth during dry periods, when the quality of feed was greatly enhanced.

Under row cultivation *Paspalum scrobiculatum* gave a total yield (and in the case of mixed pastures a yield of grass) exceeding that from swards. At wider spacing, the vigour of individual plants (i.e., yield per unit of row length) was the same, but the overall yield was reduced in proportion to the number of rows per acre, e.g.—

| —— | Sward (i.e., 7-in. rows). | 36-in. rows. | 48-in. rows. | 60-in. rows. |
|---|---|---|---|---|
| No. of rows/acre .. | 515 | 100 | 75 | 60 |
| Yield in cwt./acre .. | 49 | 100 | 82 | 67 |

At 36-in. spacing, the benefit of row cultivation was directly comparable with that effected by 4 cwt. ammonium sulphate per acre, indicating some improvement in soil fertility over and above the effects of conserved soil moisture.

In all row pastures and in lucerne swards, there was effective penetration of soil moisture from summer rainfall, and the soil attained field capacity at all depths down to 4 feet; under swards of *Paspalum scrobiculatum* the penetration was less effective. Soil moisture below the lucerne sward was, within six weeks, reduced to the wilting point at all depths down to 4 feet; whereas under row cultivation the supply persisted at relatively high levels for six weeks and there was still soil moisture available at depths of 3 and 4 feet in May and June. These effects were even more pronounced at wider spacing.

In terms of nitrogen/acre/annum, there were no significant differences in the mean yields from pure stands of *Paspalum scrobiculatum* and of lucerne. Yields from mixed pastures of *Paspalum scrobiculatum* and lucerne were appreciably less than those from pure stands of this grass, but qualitative data from a number of experiments suggest that the normal requirements for lambing ewes and/or the lesser requirements for adult dry sheep could be met by mixtures of *Paspalum scrobiculatum* and lucerne in proportions of 1 (grass) to 1 (lucerne) and 5 to 1 respectively. This would allow maximum efficiency in the utilization of all available feed. On the other hand, it appears that an intimate mixture of grass and lucerne is not essential, and that these two components (which are necessary for the provision of an adequate diet) could be grown in separate stands. The only limitation is that the two separate pastures should be within the normal diurnal range of mobile grazing animals.

(iii) *Alternative Pastures.*—A mixed pasture of Rhodes grass and lucerne provides excellent feed in summer, but has limited value in winter. On the other hand, row pastures of *Paspalum scrobiculatum* and of lucerne provide good winter feed. An experiment has been designed to gain information on alternate grazing of these three pastures as a means of maintaining growth and production in beef cattle. Grazing on these experiments commenced during the present season.

(iv) *Effect of Lucerne on Soil Fertility.*—During the past twelve months a number of experiments has yielded information on the efficiency of lucerne in maintaining soil fertility under subtropical pastures. A small proportion of lucerne has not only increased the feed value and productivity of Rhodes grass pastures, but has also increased the nitrogen content and the yield of a subsequent crop of sorghum, compared with a crop planted after Rhodes grass alone. Moreover, following this difference in sorghum yield, soils collected from the two treatments have, under glass-house conditions, shown comparable differences in the yield of *Panicum setaria*. It is clear, therefore, that, under approximately the same intensity of grazing, the admixture of lucerne with Rhodes grass has increased the fertility of this soil. On the other hand, with pastures of *Paspalum scrobiculatum,* it has been shown that under row cultivation and at a fixed intensity of grazing, the mean yield of nitrogen/acre/annum was not less than that from pure stands of lucerne. The question, therefore, arises whether the obvious benefit derived from lucerne in a Rhodes grass-lucerne mixture should be interpreted as a natural consequence of the symbiotic association of this legume with nitrogen-fixing bacteria, or whether it must be attributed to some other effect, or effects, of lucerne on the soil beneath the pasture.

### 10. PASTURE INVESTIGATIONS AT AYR, QUEENSLAND.

The Organization is co-operating with the Queensland Department of Agriculture in pasture investigations in the Burdekin Valley. These investigations include preliminary trials of pasture grasses and a grazing experiment with five grass legume mixtures.

(*a*) *Species Trials.*—The species under preliminary examination are *Paspalum scrobiculatum, Paspalum dilatatum, Panicum maximum, Panicum antidotale, Pennisetum clandestinum, Melinis minutiflora, Medicago sativa, Pueraria phaseoloides,* and *Glycine javanica.* These are planted in all possible combinations. The legumes are also being examined separately.

(*b*) *Grazing Experiment.*—The objective of this experiment is to obtain some basic information about irrigated pastures under tropical conditions and to obtain a measure of the possible return from them in terms of pounds of beef per acre. The experiment includes five mixtures—

(1) Rhodes grass + control (*Stylosanthes sundaica*),
(2) Para grass (*Brachiaria mutica*) + *Clitoria ternata,*
(3) Para grass + centro (*Centrosema pubescens*),
(4) Guinea grass (*Panicum maximum*) + *Phaseolus,*
(5) Guinea grass + stylo (*Stylosanthes gracilis*).

The experiment occupies an area of 25 acres and will be grazed by 30 steers. There are four blocks of each pasture mixture and these will be both irrigated and grazed in rotation. Data will be obtained on pasture yields, cattle weights, and soil moisture. This experiment involved considerable preparation, including the clearing of land, erection of fences, and laying down water pipes. The mixtures have now been established and it is planned to commence grazing in July, 1950.

### 11. WEEDS INVESTIGATIONS.

(*a*) *Effects of Plant Growth-regulating Substances on Perennial Weeds.*—Studies have continued on the use of plant growth-regulating substances in the control of a number of serious perennial weeds. Work on hoary cress (*Cardaria draba*) has shown that a reduction of 70 per cent. in the number of rosettes can be achieved by a single application. This reduction can be secured in a growing wheat crop with little injury to the crop and with increases in yield up to 24 per cent. due to reduced competition by the weed. The esters gave a greater degree of control than did the corresponding salts of phenoxyacetic acid.

The results of spraying skeleton weed (*Chondrilla juncea*) at varying stages of growth and with a wide range of plant growth-regulating substances at various strengths indicated little promise of control by this means. Although the number of rosettes was very considerably reduced (by as much as 90 per cent. in the months shortly after spraying) the population subsequently increased rapidly towards pre-treatment levels. Plants killed to a depth of a few inches often produced several regrowth shoots from the surviving taproot. It is concluded that the plant growth-regulating substances available as herbicides will not control established stands of skeleton weed.

Promising results have been obtained on blackberry (*Rubus fruticosus*) using compounds of 2, 4, 5-trichlorophenoxyacetic acid (2, 4, 5-T), but the same substances have had no apparent effect on bracken (*Pteridium aquilinum*).

(*b*) *Control of Perennial Grass Weeds.*—Studies of the effect of petroleum, shale, and coal-tar oils have been continued, using *Paspalum dilatatum* as the main test plant. Trials of time and frequency of spraying have been continued. Further trials have confirmed work previously reported on the relation between speed of action, toxicity and chemical composition. More intensive chemical work on the oils, whose field response is known, is now confirming and extending the results obtained to date.

The effects of rates of spraying with two oils of widely different action have been investigated in detail. The dosage-toxicity curve for any one oil is discontinuous, and below a certain critical value the effect of oils appears to be to remove only the top growth. Oils which differ widely in toxicity at the higher rates have similar effects below this critical rate. This result is important both in the commercial application and in the development of sound testing procedures. Large-scale trials are in progress to determine the commercial possibilities of the methods developed.

A preliminary trial was laid down to test various compounds for the control of Johnston grass (*Sorghum halepense*). Varying rates of allyl mixed chlorophenyl carbonate, trichloracetic acid, and two oils were tested. A single application of trichloracetic acid at the rate of 200 lb./acre completely controlled the weed and three months after treatment the plot was covered with burr medic (*Medicago denticulata*). Disappointing results were obtained with all other treatments.

(*c*) *Mintweed Control.* — Experiments conducted from the Cooper Laboratory, Lawes, Queensland, have shown the value of plant growth-regulating substances in checking the growth of mintweed (*Salvia reflexa*) and thereby permitting increased yield of summer crops. A paper has been prepared on this work.

(*d*) *Timber Regrowth Control.*—Investigations in Queensland into chemical control of forest timber regrowth, using growth-regulating substances, have continued and the effectiveness of these compounds when applied to frilled trees of young blue gum (*Eucalyptus tereticornis*) is being compared with that of commercial arsenical preparations. Experiments carried out at different times of the year have given varying results, but in general, the sodium salt of 2, 4-dichlorophenoxyacetic acid (2, 4-D) has been at least as effective as the arsenicals, and in some cases more effective. Using the cheapest available salts of this compound, a 1 per cent. solution could be applied at a cost comparable with that for arsenical preparations.

(*e*) *Mistletoe Control.*—Collaborative investigations with the Forestry and Timber Bureau have been continued. Copper sulphate pills inserted into the trunk of the host proved more satisfactory than liquid doses because of lesser damage to the host, but are much slower in their effects. About 50 per cent. control of mistletoe has been achieved with copper treatments, without serious injury to the host. However, the emphasis has been transferred from inorganic poisons to 2, 4-D, as better results with less injury to the host have been obtained with injections of this substance. Further treatments with 2, 4-D and six other hormone-like substances have been made.

The creeping mistletoe (*Phrygilanthus* spp.) appears to be more susceptible to 2, 4-D than the pendulous type (*Loranthus* spp.), whereas the reverse holds for copper sulphate.

(*f*) *Tracer Element Investigations.*—Zinc is not translocated into mistletoes as effectively as copper or iron, when injected into the trunks of hosts.

Phosphate applied to the leaves of skeleton weed may be located in the roots at a 16-in. depth three weeks after application. Accordingly, tests are being made with phosphate derivatives of poisons with a view to more effective translocation.

(*g*) *Translocation of* 2, 4-*D.*—The effect of including various electrolytes in 2, 4-D solutions is being investigated. Under some conditions magnesium chloride may increase the remote toxicity of 2, 4-D, whereas calcium chloride and lithium chloride may decrease it. Some evidence has been obtained that there is a negative correlation between local injury and remote toxicity. Experiments are continuing, to determine the factors responsible for inducing translocation of 2, 4-D from sugar-depleted leaves. In some instances translocation in the dark occurs after the removal of cotyledons, and may possibly occur in the presence of a phosphate buffer.

(*h*) *Mechanism of Action of* 2, 4-*D.*—Further studies have been made on the mechanism of action of synthetic plant growth-regulating chemicals. The discovery that 2, 4-D increased the rate of inactivation of a natural hormone, indole-3-acetic acid (IAA), by plant enzymes was followed by an investigation of the nature of the enzyme system and the mechanism of the effect. Refinements have been made to the methods for the measurement of indole acetic acid and oxygen consumption, giving improved sensitivity, accuracy, and convenience. Data obtained have led to the tentative postulation of these steps in the reaction sequence—

$$\text{indole-3-acetic acid} \rightarrow \text{indole-3-glycollic acid} \rightarrow \text{indole-3-glyoxylic acid} \rightarrow \text{indole-3-aldehyde} + CO_2$$

Hydrogen peroxide plays a key role in the oxidation.

### 12. PLANT INTRODUCTION.

(*a*) *Introduction and Exchange of Plants and Seeds.*—As no active overseas plant exploration was conducted during the year, the total number of samples received (632) was considerably less than the total of the previous year (1101), which included seeds of many pasture and crop plants collected in South America. These introductions were received from 41 countries, the largest numbers coming from Portugal, Greece, Canada, Holland, and Chile. It is of interest to note that plants or seeds were obtained from several countries with which normal intercourse is restricted by political and other difficulties, including Yugoslavia, Israel, Bulgaria, Union of Soviet Socialist Republics, Hungary, China and Rumania.

The types of plants introduced reflect the research activities of the Organization and the agricultural and pastoral needs of the country. Pasture and forage plants comprise the largest group, and particular attention has been given to pasture legumes, which are essential to any programme of pasture improvement. Large collections of species of medic (*Medicago*) and of clover (*Trifolium*) were obtained from countries in the Mediterranean region, included in the latter being many strains of subterranean clover for use in breeding studies. Several varieties of rice and cotton were introduced for trial in the Northern Territory and the Kimberley region of Western Australia, where these crops may become of major economic importance. Further large collections of wild onions and relatives of other crop plants were obtained for use in disease studies, while other notable introductions include *Strophanthus sarmentosus,* the source of a drug used in the treatment of rheumatoid arthritis, and canaigre (*Rumex hymenosepalus*), which is receiving much attention as a source of tan extracts.

In exchange for this material, 1,842 seed and plant samples were sent to 47 overseas countries, among which India and Canada took the first places. The increase in overseas requests in recent years indicates the great interest in Australian plants, stimulated by the preparation and distribution of an annual seed list.

The progress of trials of many of the introduced plants is reported hereunder, and more fully in the mimeographed *Plant Introduction Notes,* the first issue of which was distributed during the year. In addition to trials by the C.S.I.R.O., many samples are supplied for trials by the State Departments of Agriculture and other research organizations within Australia. More than 700 samples have been supplied for such trials during the year.

(*b*) *Pasture and Forage Plant Trials.*—Trials of introduced pasture and forage plants have been conducted at each of the quarantine plant introduction stations, Canberra, Redland Bay, Lawes, Katherine, and Perth, and also at several other regional stations in various parts of Australia. Most of the latter trials are made in co-operation with other sections of C.S.I.R.O., or with the State Departments of Agriculture.

(i) *Trials at Quarantine Plant Introduction Stations.*—While none of the more recent grass introductions under trial at Canberra, Australian Capital Territory, shows clear evidence of superiority to such well-established species as *Phalaris tuberosa,* many of them may prove useful in combination with the standard species, and may provide useful grazing during the periods of low production. To test this more fully, a trial has been established in which several grasses are being grown in plots in association with phalaris and the Bacchus Marsh strain of subterranean clover.

Several species of *Bromus* have continued to show promise, including a number of natural hybrids from California. Twelve strains of *Bromus hordeaceus,* also from California, have been subjected to further trial, five of them showing evidence of high productivity. Some of these may prove of value in some parts of Western Australia which are dependent upon annual pasture plants. *Bromus coloratus* has continued to be outstanding among the perennial species of the genus included in a small grazing trial at Canberra, and a satisfactory stand of plants has been maintained.

Woolly-pod vetch (*Vicia dasycarpa*) has been the outstanding species in the second year of a forage crop trial at Canberra, while among the newer introductions a strain of common vetch (*Vicia sativa*) from Argentina shows great promise.

About 200 pasture introductions are under test at Redland Bay, Queensland, the major portion comprising collections made in South America during the summer of 1947-48. The nursery rows have been sampled at six-weekly intervals throughout the year to obtain growth curves and correlations between growth periods and seasonal changes. Concurrently, changes in percentage moisture, nitrogen, and protein are being studied. These data combined with frequent qualitative assessments will simplify the selection of a limited group of species for detailed study in subsequent seasons.

At present, the most promising grasses include species of *Paspalum,* especially the leafy decumbent strains of Bahia grass (*Paspalum notatum*) and *Paspalum humboldtianum,* and species of *Tetrachne* and *Themeda.* Several legumes are promising, notable among these being species of *Desmodium* and *Indigofera*. *Desmodium uncinatum* and *D. canum* are both very promising for wet coastal areas, with high production in summer and good protein content. *Indigofera endecaphylla* produces a dense leafy trailing growth to 1 foot deep in late summer and is rich in protein, while in contrast *I. suffruticosa* forms erect bushes particularly useful for autumn grazing. The progress of work with the wild peanuts (*Arachis* spp.) has been hampered by low seed production, and this problem is receiving attention.

The value of perennial grasses in the Northern Territory depends largely upon their ability to retain succulence and nutritive value after the end of the short summer rainy season. The leaf/stem ratio of mature plants is a useful index to this succulence, and accordingly determinations of this ratio have been made for many of the more promising introduced grasses under trial at the Katherine Station. The grasses tested show ratios varying from 38 per cent. for a hay type of Buffel grass (*Cenchrus ciliaris*) to 69 per cent. for a strain of *Digitaria* from South Africa. Among the legumes similarly tested, *Teramnus labialis* ranks high with 56 per cent. leaf and 11 per cent. pods, in comparison with 41-44 per cent. leaf for the species of *Stylosanthes* tested.

Pulse crops or grain legumes offer an alternative method of providing a protein-rich fodder during the dry season. Nursery and replicated trials over four seasons have shown that varieties of *Phaseolus* are particularly attractive for this purpose, and several introductions are very well adapted to the growth season and to mechanical harvesting. An introduction of Tepary bean (*Phaseolus acutifolius* var. *latifolius*) gave a mean yield of about 1,450 lb./acre of protein-rich seed in a replicated trial, while strains of mung bean (*Phaseolus aureus*) and black gram (*Phaseolus mungo*) are also promising. Other introductions of interest in this group include fodder types of soybean and guar (*Cyamopsis tetragonoloba*). The relatively high proportion of shrivelled seed in some of these plants presents a problem which is being further studied.

Trials of pasture and forage plants have continued at the Institute of Agriculture, Perth, with subsidiary trials at Kojonup and Wokalup.

At Perth the most promising perennial grasses were *Brachiaria decumbens, Bromus unioloides, Bromus maritimus, Ehrharta villosa, Hyparrhenia hirta, Melininis minutiflora,* and *Panicum* sp. (Makarikari grass). The most promising annual grasses were a strain of *Lolium multiflorum* and one of *Lolium rigidum.* One annual pasture legume, *Trifolium globosum,* grew well, while numerous strains of *Lathyrus sativus* and a few vetches (*Vicia* spp.) were promising in the grain legume group.

At Kojonup, a most unfavorable year was experienced and the only pasture introduction of any promise was a strain of *Lolium rigidum.*

The results at Wokalup were similar to those of 1948, *Bromus popovii, Dactylis glomerata, Festuca elatior, F. pratensis, Melinis minutiflora, Panicum* spp., and *Phalaris* spp. being promising.

The projects with grain legumes again drew attention to the value of one-flowered vetch (*Vicia articulata*), particularly in areas of heavy red-legged earth mite infestation. Early planting gave higher yields than late plantings, and 30-45 lb./acre appeared to be a suitable rate for commercial plantings.

(ii) *Regional Trials.*—Regional trials of pasture and forage plant introductions have the dual objective of finding the most useful varieties for any one centre and of assessing the regional adaptability of introductions found promising at one of the primary centres.

At Armidale varieties of tall fescue (*Festuca arundinacea*) and *Bromus inermis* have shown good establishment and development under sward conditions, but their ultimate value will only be determined when forage yields have been obtained over a period of years.

*Stipa hyalina* has established well in a sward trial at Trangie, and may prove to be a valuable grass in this area. It has made attractive development under single plant conditions and has a relatively soft seed and awn.

A Mediterranean strain of cocksfoot (*Dactylis glomerata*) has been the most productive grass in trials extending over three years at Curlewis, New South Wales. A newer introduction of *Sorghum almum* has proved about equal in yield to the strain previously reported promising, and is apparently free from possible toxicity.

*Lathyrus ochrus,* from Palestine, has given very promising results as a winter-growing green manure in the Mildura area because of its rapidity of development, large bulk, good seed yield, and ease of harvesting. It is receiving an extensive trial on several vineyards during the present season.

(*c*) *Trials of Vegetable Oil Plants.*—Investigations with linseed have been continued at Lawes, Queensland. In a variety trial good yields were obtained despite the dry season, and the commercial value of the crop is thus established by success in four of the last five years. In 1949 the best yielding varieties were Hindi and Walsh, each giving 19.5 bus./acre. The relative success of these varieties, and of the rust-resistant varieties Newland and Malabrigo, can be attributed largely to an outbreak of rust. In previous years the rust-susceptible Indian types have consistently outyielded them. A progress report on the linseed investigations at Lawes and other centres in south-eastern Queensland has been published. Further trials are in progress.

Further trials at Katherine have confirmed the value of peanuts and rapeseed at this centre. Two Argentine varieties of peanut have given yields of about 1,600 lb./acre in a replicated trial, being fully equal to the Virginia Bunch variety commonly grown in the district. The best of the rape seed varieties tested, "Raya L-9" from India, has yielded 1,250 lb./acre as a winter irrigated crop. Several introduced varieties of sesame have given good yields, averaging over 1,100 lb./acre, in nursery plots. If these yields are maintained in the non-shattering types recently introduced, the crop may prove of value in northern Australia, as the seeds have a high oil content.

Soybean investigations at Lawes have been restricted to trials with promising recent introductions from South Africa and China. Some selections made at Lawes are promising in nursery rows, and work with them will be continued. In a soybean variety trial at Griffith, New South Wales, the highest yields were obtained from the earliest sowing (October 25), and a marked reduction in yield resulted from later sowings. The varieties included in the trial, all of which had been selected for suitable maturity, did not differ significantly in yield, but the highest yield (1,715 lb./acre) was given by the American variety "Lincoln". Various fertilizer treatments produced no significant increases in yield.

Trials are also in progress with varieties of sunflower and safflower. A trial of Niger Seed (*Guizotia abyssinica*) at Katherine gave a very low yield, and this West African oilseed appears to have little prospect of economic value.

(*d*) *Trials of Technical Plants and Cereals.*—Progress of work with guar (*Cyamopsis tetragonoloba*) has been impeded by uncertainty about the possible commercial utilization of the seeds in Australia. As the cost of producing the seeds would be greatly reduced if the plants could also be used for green manure or fodder, trials have been conducted to assess their suitability for this purpose. In a trial at Griffith, guar was greatly inferior to a variety of cowpea and to the Ototan variety of soybean as a summer-growing green manure, but it has shown more promise in tropical regions. Further introductions of guar have been made from India in the search for a variety which might best meet the need for a dual-purpose crop. Poor nodulation may be in part responsible for erratic yields of guar and for the occasional failure to produce plump seeds. However, the use of special *Rhizobium* strains from America did not improve nodulation in a trial at Redcliffs, Victoria.

Following successful preliminary trials of introduced oat varieties at Kojonup, Western Australia, three varieties (Frazier, Fulwin, and Trojan) are being included in large-scale field trials. The object of these trials is to obtain varieties which can be grazed in winter and still give a high grain yield. Similar trials at Wokalup in the wetter dairy belt of Western Australia indicate that some of the introductions are at least as good as any available commercial varieties. Barley trials are also in progress and the results to date are promising.

(*e*) *General.*—While the results reported above are based principally on variety trials at various centres, it should be emphasized that successful plant introduction is ultimately dependent also upon investigations in several related fields. The time which could be devoted to such investigations has necessarily been limited by the pressure of other work, but it is possible to record progress in some directions during the past year.

A study has been made of the distribution of grasses throughout the world, and the relationship of this distribution to climatic and other factors. This has shown that the pattern of grass distribution is closely correlated with that of certain simple climatic factors. It may, therefore, be possible to use direct comparisons between the grass flora of different regions as an index of their climatic similarity, and hence to define more objectively the regions in which introduced plants are most likely to prove of value.

From quite a different angle, the value of many introductions will ultimately lie in their utilization as breeding material. Many of the introduced varieties which are of no immediate commercial value provide valuable genetic material. Thus, an extended use of safflowers and sunflowers as commercial crops is in part dependent upon the development of spineless and hybrid varieties respectively. Investigations have, therefore, been made of the inheritance of the spineless character in safflowers and of the mechanism of flowering and seed-setting in sunflowers. The results of these investigations will be utilized in the development of improved varieties in later years.

(*f*) *Herbarium.*—The Divisional herbarium has now more than 21,000 specimens, including 2814 mounted and laid in during the year. The additions comprise principally plants collected in the course of pasture and vegetation surveys made by Divisional officers in New South Wales, Queensland, and the Kimberley region of Western Australia, and specimens obtained by officers of the Division of Entomology at Barrington Tops and the extreme north-western portion of New South Wales. The collections have also been enriched through the exchange of material with leading herbaria in the United States, Uruguay, Argentina, Paraguay, Holland, Portugal, and South Africa. By arrangement with the Botanic Museum and Herbarium, Brisbane, many interesting specimens have been obtained from that institution.

The identification of the material referred to above has taken up most of the time of the systematic botanist, and many collections are still awaiting attention. It has been found possible, however, to make some progress with a revision of the Australian species of *Triodia* R.Br. This is now almost complete, and line diagrams showing the more important features of each species are in course of preparation. Collections of seeds of native plants have been made for use in overseas exchanges, and a course of lectures in systematic botany has been given to technical officers.

In addition to the above activities which are directly concerned with the research activities of the Organization, the systematic botanist has continued to act as secretary of the Systematic Botany Committee of A.N.Z.A.A.S. Two numbers of *Australasian Herbarium News* were prepared for publication during the year, and work has continued on the compilation of a list of important systematic botany publications available in Australian libraries. Arrangements were made with the Scientific Liaison Office in London for the preparation of microfilm photographs of Australian type specimens in the Lindley Collection at Cambridge. These have now been received and distributed, and have proved of great value. It is intended to extend this work to cover other botanical material.

### 13. KATHERINE EXPERIMENT STATION.

During 1949-50 the first results from the dry-land agriculture investigations on the red-brown calcimorphic soils of the Tipperary Land System were reported.

The range of suitable crops in this region lies within that of the warm temperate and tropical group of annual crops. Although exotic crops have been under examination, research has been mainly confined to the endemic crops such as grain sorghum (cereal), peanuts (oil and proteins), cotton (fibre), and pastures (grazing rotation). The two exotic crops which have received most attention are bulrush millet (*Pennisetum typhoides*) and the Geocarpa ground nut, chosen as a marginal area cereal and high protein producing crop respectively.

A study of length of season in relation to these crops has been undertaken. Experiments indicated that the normal planting date for summer crops grown under natural rainfall conditions is about the first week in December or later. The length of the growing season appears to be adequate for all these crops with the possible exception of cotton.

Apart from variety comparisons and climatological studies, field investigations under dry-land conditions have concerned soil fertility and plant spacing. The actual crop yields obtained in this first season cannot be accepted as final because of the need for further information on these two factors. Yields of all crops were low to moderate, but fertilizer responses were observed and it is probable that higher yields will be obtained when fertility requirements are better known. The major response on these soils has been to superphosphate, but non-leguminous crops have also responded to nitrogen.

An investigation with numerous minor elements indicated that they are not limiting factors to crop production on virgin soil. Where pasture species have been sown over previous fertilizer trials, marked responses to residual fertilizer have been observed.

Variety comparisons have been made in peanuts, cotton, and sorghum. For peanuts and cotton, it would appear that most satisfactory yields will be obtained from varieties other than those selected for southern Queensland conditions, where these crops are at present most widely grown.

The examination of further varieties is planned.

Pasture investigations on cultivated land (*see* also Section 12 (*b*)) have mainly concerned Birdwood grass (*Cenchrus biflorus*), Buffel grass (*Cenchrus ciliaris*), Townsville lucerne (*Stylosanthes sundaica*), two strains of *Stylosanthes gracilis*, and introduced strains of *Cenchrus ciliaris*. New experiments have included Rhodes grass (*Chloris gayanus*), Guinea grass (*Panicum maximum*), *Andropogon gayanus*, and the legume *Clitoria ternata*. In addition, Townsville lucerne has been successfully established on heavily grazed natural pastures. Establishment is improved by application of superphosphate and by a rough surface cultivation. This species failed to survive in ungrazed pastures.

The investigations on the levee soils have mainly concerned tobacco and new plant introductions. The results are reported elsewhere (*see* Section 18).

### 14. KIMBERLEY RESEARCH STATION.

The investigations at the Kimberley Research Station, which are being conducted in co-operation with the Western Australian Department of Agriculture, have been summarized in a progress report prepared by the Joint Supervisory Committee. As these investigations have now reached the stage when the agronomic problems of the Ord River flood plain and the more important fields of agronomic research can be more closely defined, it is planned that a Research Officer should be located at the Station within the next few months.

(*a*) *Soil Fertility Problems.*—Numerous experiments have now been conducted which indicate that superphosphate is a major requirement for crop and pasture production. Under certain conditions nitrogen and potash also appear to be important. However, in spite of the application of major elements there appears to be a problem of soil fertility requiring further investigation. The possibilities of minor element deficiency are being investigated at present.

(*b*) *Pasture Investigations.*—Pasture grasses which have been established for two or more seasons have shown a marked falling off in production and the extreme importance of a satisfactory balanced pasture mixture has been indicated. Species investigations have demonstrated that several pasture grasses and legumes are reasonably well adapted to the conditions and these are now being examined in various combinations. The more promising species include Para grass (*Brachiaria mutica*), *Paspalum scrobiculatum*, Rhodes grass (*Chloris gayanus*), *Andropogon gayanus*, Guinea grass (*Panicum maximum*), Townsville lucerne (*Stylosanthes sundaica*), *Stylosanthes gracilis*, *Clitoria ternata*, and the common crop varieties of peanuts. A stockyard and a weighing machine have now been constructed on the station and actual live-weight increases in beef cattle will be obtained from these pastures.

(*c*) *Crop Evaluation and Variety Comparison.*—Of all the crops tried, peanuts have been most successful and have given commercial yields. In the case of cotton, grain sorghums, and rice, it is now clear that special attention will have to be paid to the selection or production of suitable varieties for these special conditions. Maize and sunflowers have not proved successful on the heavy Cununurra clay. New crops being investigated during the current season are sugar cane and linseed. In both cases a number of varieties are being compared.

(*d*) *Irrigation Technique.*—Furrow irrigation has proved a satisfactory method of irrigating crop species. The data which have been accumulated indicate that on this heavy soil rice uses five or more acre feet of water to mature a crop. Dry season annual crops have required 1-2.7 acre feet. Perennial pastures have utilized about 1.3 acre feet and annual crops other than rice grown during the wet season have required only 0.15-0.71 acre feet. An experiment to determine the most efficient frequency of watering of perennial pastures has been commenced.

(*e*) *Pests and Diseases.*—Since these investigations commenced, a large proportion of experiments have been ruined by the depredations of pests, principally birds and grasshoppers, in spite of strenuous efforts on the part of the limited staff available. On the other hand, plant diseases have been of relatively minor importance and most have been satisfactorily controlled by normal methods.

### 15. REGIONAL SURVEYS.

During the year 1949-50 the Northern Australia Regional Survey has been established as a permanent Section under the title of Land Research and Regional Survey.

(*a*) *Ord River-Victoria River Region.*—A survey of the drainage basins of the Ord and Victoria Rivers in the east Kimberleys and north-west of the Northern Territory was commenced. The survey party, including a geologist seconded from the Commonwealth Bureau of Mineral Resources, a soils officer, and an ecologist. was in the field from June to September. The area surveyed extended from Wyndham and Katherine in the north to the inland deserts south of Halls Creek and Wave Hill, and covered an area of about 70,000 square miles of country. Numerous botanical, rock (bauxite), soil, wood, and pasture samples were taken and are being examined by the appropriate authorities. Preliminary mapping of the country has been commenced in the laboratory. The survey party will spend another year in the field in this region.

(*b*) *Barkly Region.*—Compilation of data and mapping of the Barkly Tablelands region has been continued. The map of the geomorphological units and the map of the land estimates of this region have been completed and are now being printed. A study has been made of the distribution of bores and natural waters and the country served by them, and an estimate has been made of the country where additional water supplies are required. Underground water has been studied by the geologist of the party and a contour map of the surveys of the sub-artesian water supplies has been prepared. Numerous botanical specimens obtained from this survey have been identified. The preparation of a report on the region is in progress.

(*c*) *Townsville-Bowen Region.*—The unit has been requested to make a survey of the Townsville-Bowen region which includes the Burdekin Valley. This survey is planned to commence in mid-August, 1950, and will occupy a period of six to eight weeks.

### 16. FRUIT INVESTIGATIONS.

Work on vine and citrus fruits in progress at Merbein and Griffith is outlined in Chapter IV., and investigations into insect pests, such as mites and woolly aphids, are described in Chapter IX.

(*a*) *Apple and Pear Investigations at Stanthorpe, Queensland.*—The investigations at Stanthorpe are designed primarily to discover apple rootstocks which give a better performance under Australian conditions than the commonly used Northern Spy and seedling stocks, are easily propagated, and are immune to attack by woolly aphis. Attention has also been given to a search for improved rootstocks for pears and plums. This work has been in progress for sixteen years.

During the 1949-50 season a record crop was set on all apple trees in the experimental plots. In the main orchard planting in which various Malling apple rootstocks are being compared with seedling and

Northern Spy stocks, Jonathan trees on Malling XII. stocks gave the highest average yields (many over 9 bushels per tree). Jonathan on Malling XVI. carried up to 9 bushels per tree. On the second orchard planting, which compares the performance of Jonathan and Granny Smith varieties upon Malling No. XII. stock, Ivory's Double Vigour, and the local selection S4, a pruning trial was also conducted. The lightest pruning treatment (the Wickens method) continued to give the highest yields of good quality fruit on all rootstocks. Since these trees were planted in 1939, Jonathan trees on Malling XII., when light pruned, have borne 172 per cent. greater crops than when hard pruned on the same rootstocks; the differences for Jonathan on Stock S4 and on Ivory's Double Vigour are 192 per cent. and 150 per cent. respectively.

A new orchard trial is being planted this winter with Jonathan on 11 of the new woolly aphis immune rootstocks raised by the East Malling Research Station. Nursery trials, including one in which the variety Delicious is being tested on the four Merton stocks, local selection S4, Northern Spy, and its own roots, are being continued. Small numbers of Merton rootstocks have been distributed to nurserymen and a larger quantity through the Deciduous Section Group of the Committee of Direction of Fruit Marketing in Queensland.

The nursery trial of William Bon Chrétien pears on five vegetatively propagated rootstocks has reached its seventh year and will be abandoned. The largest trees have been produced by rootstocks D3 and Pyrus Calleryana and the largest crops by D3. The relative performance of the other three stocks in this trial has been in the order of selection C7, D4, and B1.

Studies this season confirmed the observation that Jonathan and Granny Smith are both good pollinators for the variety Delicious which requires cross-pollination. However, in some seasons Delicious flowers later than Jonathan and Granny Smith, with which it is commonly interplanted, and pollination difficulties arise. Pollen germination tests show considerable variation in pollen viability from season to season. Studies are being continued in connexion with the problems of replacing apple trees in soil which has previously carried apples. Results indicate that the possibility of root toxins affecting replacement is remote. Some observations have been made on the occurrence of nematodes on apple roots in the district and also of mycorrhiza. These occurrences are being studied in relation to the tree replacement problem. During the year a new trial was planted using Jonathan as scion and comparing a range of a dozen stocks which are reputed to be resistant to woolly aphis.

## 17. DRUG PLANTS.

The general description and purpose of investigations on drug plants will be found in previous reports, particularly in the Annual Report of C.S.I.R. for 1945-46.

(*a*) *Opium Poppy* (Papaver somniferum).—The breeding and selection programme commenced in 1944, which aimed to combine the most desirable characters of promising varieties, has been completed. A final yield trial at Canberra again revealed the superiority of many of the bred lines to the parental material. Improved types yielded 50 per cent. more morphine per acre than the variety grown commercially during World War II. The general results of the opium poppy improvement programme were published during the year.

Nucleus seed stocks of varietal and breeding material have been set aside for permanent storage at Canberra. Results of germination tests suggest that stored seed is viable up to ten years and possibly much longer. A few plots to increase further the seed stocks of certain selected improved lines are being grown during the current season.

(*b*) Duboisia *Spp.*—Work has been continued on the chosen strains of the native species *Duboisia myoporoides* and *D. leichhardtii* and the intermediate types between these two species, for the selection of superior lines for hyoscine and atropine production under cultivation. Studies have also been continued on the general botany and physiology of these species.

Improved assay methods which were described in the First Annual Report of C.S.I.R.O. (p. 24) have made it possible to compare critically the hyoscine-yielding ability of seven selected clones of northern *D. myoporoides*. Observations at Canberra have shown that genotypes exist within *D. leichhardtii* and both the northern and southern types of *D. myoporoides* which are relatively resistant to damage by the 20° F. or so of frost experienced during the winter at Canberra.

No further advances have been made in the study of the propagation of these species. In spite of continued efforts to improve the technique used, only some 50 per cent. of the cuttings are rooted satisfactorily. An examination of the morphological development of the seed and embryo has been completed. Development is normal in most respects although an unusual type of endosperm tissue growth obtains. Failure to germinate, however, continues in apparently normal seed, although a great variety of treatments, which in other cases have been used successfully to break seed dormancy, has been tried.

Grafting has continued to be used as a means of studying alkaloid synthesis. Both hyoscine and hyoscyamine were formed in tomato scions grafted on stock of southern *D. myoporoides*. Low and high hyoscine clones of northern *D. myoporoides* are being used reciprocally as stocks and as scions. Experiments have shown that intensive shading affected neither the total alkaloid content nor the percentage of individual alkaloids in trees of the northern *D. myoporoides* type growing in the fields at Canberra.

During the year a further field survey was made of the occurrence and distribution of *D. leichhardtii*. The known area of distribution was extended northwestwards and the eastern boundary more clearly delineated.

(*c*) *Survey of Native Plants for Sources of Substances of Pharmacological Value and Chemical Interest.*—A systematic search for sources of supply of pharmacological substances in native plants was commenced in 1945 (*see* 19th Annual Report of C.S.I.R.). Subsequently the survey was extended to include substances of general chemical interest and value such as saponins, alkaloids, cyanogenetic and cardiac glycosides, pigments, and oils. The survey is at present concerned mainly with the Queensland flora. Preliminary selection of plants is made by means of chemical spot tests in the field. Further examination is made by the Division of Industrial Chemistry of this Organization (*see* Chapter XVII.) and by the Departments of Chemistry in the Universities of Sydney, Melbourne, Queensland, and Adelaide and the New South Wales University of Technology and other organizations. The results of these collaborative investigations are published as institutional reports and in appropriate journals.

Over 600 preliminary tests were made during the year; approximately 95 new species were found to contain alkaloids. Almost 200 bulk samples of material were collected and forwarded to chemical collaborators for examination. Particular attention has been paid to the collection of material likely to contain steroidal saponins. Such a saponin may be found to constitute a suitable raw material for the synthesis of cortisone and other animal hormones. Through the courtesy of the Administrator of the Territory of New Guinea and Papua, a large number of varieties of yam (*Dioscorea* spp.) has been collected in this search for steroidal saponins.

By means of a semi-micro method, a large number of samples from the Queensland Herbarium and some from the New South Wales Herbarium have been spot-tested, mainly for alkaloids. This method has proved a valuable adjunct to tests on fresh material, particularly when the plants concerned are not easily accessible in the field. Fragments of herbarium specimens kindly made available by the botanist of the Commonwealth of Australia—National Geographic Society Arnhem Land Expedition 1948, have enabled a coverage to be made of the flora of northern Australia in respect of alkaloids.

During the year the overall results of the preliminary chemical work of the survey done in the field have been published. So far as alkaloids are concerned, the position may be summarized as follows: Thirty-seven families, 108 genera, and 206 species of native flowering plants (26, 15, and 13 per cent. respectively of those tested) appear to contain substantial amounts of alkaloidal substances. Nine families are particularly rich in alkaloids: Apocynaceae, Hernandiaceae, Lauraceae, Leguminoseae, Loganiaceae, Menispermaceae, Monimiaceae, Rutaceae, and Solanaceae.

Substances and extracts from native plants are being tested for mitotic action in connexion with the search for materials having anti-tumour properties (*see* 22nd Annual Report of C.S.I.R., page 18). A number of substances so selected have been forwarded to the Sloan Kettering Institute for Cancer Research, New York, for testing as anti-cancer agents.

## 18. Tobacco.

Prospects for expanding tobacco production on a sound basis under irrigation, particularly during the "dry" season in the northern part of Australia, are very promising. This development has opened up a new field of research and experimentation requiring immediate attention. Methods of production based on North American practices which were established for different environmental conditions have to be modified, new methods tested, and values for yield and quality determined. To help meet the demands created by this situation, expansion in the programme of investigations is urgently required. Initially it is proposed to give more attention to water requirements, and to the effect of growing conditions on quality as determined commercially and by chemical examination.

During the 1949-50 season, field experiments in association with the Queensland Department of Agriculture and Stock were continued in the Ayr district on the Queensland Tobacco Experiment Station established at Clare. At Katherine, Northern Territory, high yields of air-cured leaf of satisfactory quality were obtained from the experimental plots.

A chemical examination of flue-cured leaf grown at Clare in 1948 showed that "trashy" leaf, which commonly occurs in North Queensland and is of major importance in some seasons, is almost devoid of sugars. This finding is of importance, particularly because the effects of high sugar content greatly influence quality.

(*a*) *Irrigation Experiments.*—The study of water requirements, commenced in the previous year, was continued at Clare. There were four spray treatments: weekly applications of 1.5 and 2.0 inches, and the same total quantities applied throughout the season at rates expected to meet the plant's growth requirements. Measurements were made of plant growth and of the movement of water in the soil. The total water requirement for satisfactory growth was approximately 19 inches—three inches less than in 1948, owing to higher soil moisture following the heavy and prolonged wet season of 1949. Soil nitrogen as judged by plant growth was lower than in the previous season, probably because of leaching following heavy rains. Yield per acre was approximately 1,350 lb. of cured leaf, 500 lb. less than in 1948.

At the Katherine Experiment Station, Northern Territory, there were six irrigation treatments:—0.5, 1, and 2 in. per week and 1, 2, and 4 in. per fortnight. Rates of 0.5 in. per week and 1 in. per fortnight were insufficient for satisfactory growth, the plants being small and the leaves not maturing. Plot yields of air-dried leaf were of the order of 2,000 lb. per acre. From field observations it appeared that 1.5 in. of irrigation water per week would have given satisfactory results.

(*b*) *Genetics.*—(i) *Varieties.*—The study of growth characteristics of varieties was continued at Clare. Short rows of 28 flue-cured, 19 of other types, and 20 from collections made in New Guinea were grown under irrigation. The most promising flue-cured varieties were Yellow Special A, Silver Dollar, Hicks, Bottom Special, Big Jim, and Virginia Gold, all of which were obtained from North America recently. Plants from seed forwarded from Papua-New Guinea were inferior in growth, leaf characteristics, and quality. Under conditions at Clare, none was acceptable for commercial production.

(ii) *Mosaic Resistance.*—Mosaic virus disease causes loss in quality and quantity of leaf every year, particularly in North Queensland. In 1949, nine lines of breeding material containing the necrotic factor (from *N. glutinosa*) for resistance to the virus were obtained from Dr. W. D. Valleau, Kentucky, United States of America). This resistance is now being incorporated in several good flue-cured varieties. Resistant seedlings of the first generation have been transplanted at Ayr and it is expected that seed of the third backcross will be obtained before the end of 1950. The original seed received produced plants unsuitable for commercial production.

(*c*) *Diseases.*—The study of Yellow Dwarf and Big Bud viruses was continued in the greenhouse. Under natural conditions both viruses are transmitted by the same insect vector but as yet, transmission by dodder has been obtained only with Big Bud. Transmission of Big Bud, by grafting, to potato was confirmed and subsequent investigations, reported elsewhere (*see* Section 19), have shown that this disease can be of importance under field conditions. Investigations on transmission of the viruses by the insect vector *Orosius argentatus* Evans were continued by officers of the Division of Entomology.

(*d*) *Chemistry.*—A chemical examination of cured tobacco leaf grown under irrigation at Clare showed that leaf commonly described as "trashy" is very low in sugars. Trashy leaf is brown, worthless, cured material sometimes referred to as "dead tissue". The data obtained by chemical examination, taken in conjunction with results of observations over many years, indicate that trashiness is associated with well-grown crops (high nitrogen), lack of adequate sunlight (shadiness), and relatively high night temperatures early in the harvesting period. Evidence so far available indicates that wider spacing of plants and better control of nitrogen fertilizer should help to prevent the development of trashiness.

(*e*) *Physiological Investigations.*—(i) *Water Requirements of Tobacco.*—Studies on growth, development, and reproduction of plants and the interrelations of these with soil moisture and periods of drought were continued. Decreased levels of soil moisture reduced the number and weight of leaves produced, the height of the plant, and the weight of the stem, and also delayed flowering, which nevertheless occurred at an earlier leaf stage. Temporary drought treatments had a negligible effect on the number of leaves produced and no effect on plant height, fresh weight of stem, or time of flowering. Weight of leaf was reduced under temporary drought but not as much as by reduced soil moisture levels.

(ii) *Suckering.*—Experiments on the suppression of axillary bud development by chemical growth-regulators were continued. Sucker growth from the nodes of the upper part of the plant was inhibited but on some occasions there appeared to be a degree of stimulation of the dormant buds at the base of the plant.

(*f*) *Other Investigations.*—At Katherine, Northern Territory, the fertilizer experiment was brought to a successful conclusion. There were seven treatments: 13, 27, and 40 lb. of nitrogen per acre, each with 200 and 400 lb. of superphosphate and all receiving 80 lb. of sulphate of potash, and also a no-fertilizer treatment. The plots were transplanted at the beginning of July and harvested during October and November. Yields of air-cured leaf, calculated on a per acre basis, varied from 1,700 to 2,400 lb. Results obtained with 27 lb. of nitrogen and 200 lb. of superphosphate were very satisfactory, but more fertilizer may be required in soils not previously cultivated.

In North Queensland, seedbed soil is usually heat-sterilized by burning material obtained from termite mounds. This material is in short supply. At Clare, preliminary tests with chemicals commonly used for soil sterilization in North America gave encouraging results, but none were as good as termite material. There were eight treatments, including cyanamid and urea, cyanamid alone, and DD. Cyanamid-urea mixtures, and DD, prevented nematode infection but weeds were prevalent with the latter, while seedling growth in both was not as good as was obtained in heat-sterilized seedbeds. However, the results show that chemically treated seedbeds will produce healthy seedlings.

### 19. PLANT DISEASES.

(*a*) *Effect of Origin of Potato Seed on Yield.*—It has been suggested that the results of potato trials, in which virus-diseased stocks from one part of the country are compared with healthy stocks from another part, might be disturbed by a persistent effect of the soil in which the seed was grown on its yield in the subsequent season. To check this point, a uniform sample of FX Up to Date was subdivided in 1948 and grown on three radically different soils in the Canberra area. In 1949-50 comparable lots of seed from the three soils were tested for yield in an extensive trial at Dickson, Australian Capital Territory. The results were quite negative.

(*b*) *Plant Virus Diseases.*—(i) *Potato Virus X.*—An experiment to determine the relative rates at which virus X will spread in five potato varieties was set out in 1948-49, but because of the poor growth of the plants conclusive results were not obtained. The experiment was repeated in 1949-50 under better growth conditions, but final results are not yet available.

A plot designed to measure the loss of yield due to virus X infection was set out at Dickson, Australian Capital Territory, in 1949-50. The method of infection of the experimental half-tubers by core-grafting proved inefficient, very few plants becoming infected. The progeny of these plants will be used in a further plot next season.

(ii) *Purple Top Wilt of Potato.*—A disease of potatoes, identical in appearance with that caused by the Aster Yellows virus in the United States, became prominent in the summer of 1949-50 in the Canberra region. Graft transmission to *Datura* and tomato indicated that the disease was caused by the tomato Big Bud virus. The disease has in the past been confused with that produced by *Rhizoctonia* attack, which it superficially resembles. Further studies are being made.

(iii) *Witches' Broom Disease of Lucerne.*—Further field and glasshouse observations have been made of symptom expression and seasonal recovery. A glasshouse controlled-watering experiment has been begun. It is designed to show the effect of water supply on symptom expression, the effect of the disease on yield and the effect of frequency of cutting on longevity of diseased plants. A study is being made of anatomical effects of the disease on lucerne. Further attempts at dodder and graft transmission from lucerne to lucerne have been unsuccessful, but successful transmission has been obtained by dodder from lucerne to *Vinca alba* on which virescence symptoms are produced.

(iv) *Fundamental Studies on Virus Recovery Phenomena and Chemotherapy.*—Work has begun on the use of plant tissue culture techniques for controlled studies of virus recovery phenomena. In the course of this work an attempt will be made to free potato tissue from virus X with the object of deriving FX stocks from fully infected varieties.

(*c*) *Potato Diseases.*—(i) *Common Scab* (Actinomyces scabies).—Field trials of varietal resistance to common scab were continued, using the most promising varieties selected from previous trials and new varieties recently introduced from United States of America. In experiments at Canberra and Lawes (the latter in co-operation with the Queensland Department of Agriculture), the American varieties Menominee and Ontario outyielded standard commercial varieties, and had only about a third as much scab as non-resistant varieties. Sufficient seed of these two varieties was furnished to the Queensland Department of Agriculture for a test of yield and agronomic qualities on a larger scale in 1950. The imported varieties Cayuga and 1537-12 were equally resistant to scab, but were inferior in yield. The scab-resistant varieties Russet Sebago, Yampa, and U.S.D.A. seedling 6344 were introduced from America during 1949, but have not yet been adequately tested in Australia.

(ii) Rhizoctonia solani.—Further pot and field experiments confirmed the finding previously reported, that Medium Brownell and C.P.C. 1417 have slight but definite resistance to pre-emergence sprout injury by *Rhizoctonia solani*. This resistance is too slight to be of use in a breeding programme. Several samples of seed of these varieties, grown under varying conditions, and at different stages of maturity, were compared with similarly differing samples of susceptible varieties. The results gave no support to the hypothesis that apparent varietal differences in susceptibility to *Rhizoctonia* were due merely to difference in stage of maturity or source of the seed samples used. Although different samples of seed of a given variety varied in susceptibility to *Rhizoctonia*, Medium Brownell and C.P.C. 1417 were consistently less susceptible than comparable samples of Red Warba and Russet Burbank. Two reputedly resistant clones of *Solanum andigenum* were introduced from La Molina, Peru, for comparison with Medium Brownell and C.P.C. 1417, after multiplying the seed in quarantine.

(iii) *Late Blight* (Phytophthora infestans).—Sixteen *Phytophthora*-resistant hybrids from Dr. W. Black (Scotland) and five from Canada were tested for resistance to five isolates of *P. infestans* from New South Wales, Tasmania and Victoria. Tests with three other isolates are in progress. The foliage of all these hybrids was practically immune to all isolates tested, developing only minute black necrotic specks, as the result of a hypersensitive reaction. Under similar conditions, the foliage of susceptible varieties was rapidly and completely destroyed; varieties reputed to have a useful degree of partial field resistance, e.g. Sebago and Menominee, differed from the most susceptible varieties only by a day or two's delay in the destruction of the foliage. The Scottish hybrids so far tested included representatives of each of the following groups:—

(1) Foliage resistant to Black's *Phytophthora* strains A and C, susceptible to B, E and F;
(2) Foliage resistant to strains A, B and C, susceptible to E and F;
(3) Foliage resistant to strains A, B, E and F, susceptible to C.

As all Black's hybrids tested were resistant to all *Phytophthora* isolates tested in Canberra, it would appear that only strain A, or a local strain or strains similar to it in pathogenicity, was present in the Australian isolates tested. However, it is possible that further search might reveal others.

Tuber inoculations showed that foliage resistance to *P. infestans* was not necessarily correlated with tuber resistance. No variety with highly resistant foliage had completely susceptible tubers, but tuber infection from artificial wound inoculations ranged from 0 to about 70 per cent. of that in susceptible control varieties.

It is doubtful whether the agronomic characters of any resistant varieties tested would enable them to compete with standard Australian susceptible varieties, but they should be of great value in breeding for resistance to late blight.

All the *Phytophthora* isolates tested were obtained from potato. None was as pathogenic to tomato foliage as to potato; some were moderately pathogenic and others had little or no effect on tomato.

Although it is possible to grow local isolates of *P. infestans* on artificial media, it is considered more satisfactory at present to maintain stock cultures in living potato tubers, and to produce initial supplies of inoculum on sterile raw potato slices, from which it is multiplied as required on living potato foliage. Abundant sporangiophores were produced on leaves of kangaroo apple (*Solanum laciniatum*), a perennial native shrub which could conceivably act as a reservoir of inoculum under natural conditions.

(*d*) *Turf Diseases.*—Four fungicides were tested for the control of "dollar spot" (*Sclerotinia homoeocarpa*) on a green at a golf course in Canberra. Excellent control was given by phenyl amino cadmium acetate and by a calcium-zinc-copper-cadmium-chromium complex, each applied about once a fortnight during late spring, summer and early autumn. These caused no injury to the turf. A mixture of mercuric and mercurous chlorides, applied about once a month during the same period, gave equally good control, but slightly retarded growth of the turf. Tetramethyl thiuram disulphide was relatively ineffective.

(*e*) *Tomato Diseases.*—A study of the effect of nutrition on the course of development of *Fusarium* wilt of tomato commenced in 1947 has been concluded. In sand culture, using the variety Bonny Best, it was shown that the severity of disease decreased with increasing concentration of nutrients from one-tenth to five times normal. There was, however, no clear evidence that the beneficial effects of higher nutritional status of the host were other than a delaying of ultimate death due to a decreased rate of disease development. In the soil used, a phosphate-deficient brown clay loam from Dickson Experiment Station, Australian Capital Territory, no beneficial effects from high rates of application of a complete fertilizer, either with or without lime, could be demonstrated.

It is considered that attempts to control this disease by attention to fertilizer practice would be impractical.

(*f*) *Take-all of Wheat.*—Experiments were continued with wheat grown in drums and subjected to various treatments. It was found that *Ophiobolus graminis* survived a two-year fallow and an oats-fallow rotation. When a culture of *O. graminis* was added to some drums the yield and the general condition of the wheat plants were better than in the controls.

(*g*) *Seedling Blight.*—It often happens that sown seed fails to germinate, or does not show above ground, or the seedlings perish shortly after emergence. Studies are in progress to determine the factors concerned in these losses. It was shown that with William Massey garden peas there was a decidedly better emergence with seed of a good green colour than with peas of dull green or yellow-green.

With poppies, losses of seedlings in soil from the Dickson Experiment Station were controlled by liming.

(*h*) *Brown Rot of Stone Fruits.*—Detailed observations are being made yearly on the occurrence of brown rot in stone fruits, to determine as exactly as possible the factors influencing the incidence of the disease. A 2-acre planting has been established at the Dickson Experiment Station to study the effects of soil and soil management on losses.

(*i*) *Use of Antibiotics in Plant Disease Control.*—Preliminary work has commenced on the use of antibiotic substances for controlling plant diseases. Work will be concentrated on the diseases which have responded poorly or not at all to normal control measures. Particular attention is to be paid to brown rot of stone fruit (*Sclerotinia fructicola*).

(*j*) *Collection of Cultures of Plant Pathogens.*—A start has been made on the assembling and maintenance of a collection of fungal and bacterial plant pathogens at Canberra. This collection is designed to assist plant pathologists throughout Australia by providing a centre where types may be readily obtained for identification, research and teaching.

### 20. VEGETABLES.

The work on vegetables in progress at the experimental stations at Merbein and Griffith is reported in Chapter IV., Sections 2 and 3, and investigations on insect pests are outlined in Chapter IX.

(*a*) *Virus Resistance in Potatoes.*—It has been demonstrated that hybrids possessing complete field resistance to the mosaic viruses A, X, and Y, and with good yield and tuber quality, can be developed from crosses between ordinary potato varieties. There is thus no reason why future commercial potato varieties should not possess these properties and so avoid the yield reductions caused by the mosaic viruses. To this end co-operative work with officers of the Victorian, Tasmanian, New South Wales, and Western Australian Departments of Agriculture is in progress.

Leaf roll is the most important virus disease of the potato in Australia and overseas. It has been found very difficult to develop hybrids with a high resistance to it. A study of the leaf-roll reactions in plants grown from tubers, which were inoculated by feeding virus-bearing aphids on the sprouts, has led to the development of a few hybrids with a lethal reaction to leaf roll. It is thought that hybrids with this property may have a high field resistance to this disease.

Spotted wilt is at times a troublesome disease of potatoes, and a study of the factors leading to resistance in varieties and hybrids has been in progress for some time. Certain varieties like Katahdin are highly resistant and transmit this character to a fair proportion of the seedling progeny.

(*b*) *Spotted Wilt Resistance in Tomatoes.*—Spotted wilt is the most important virus disease of the tomato and causes the greatest losses in early crops grown in the metropolitan areas of Australia. A high degree of resistance associated with a line of *Lycopersicon pimpinellifolium* has been transmitted to hybrids, which, through a system of backcrossing, are approaching types with fruits of commercial size. This has been made possible by developing glasshouse testing methods which give results comparable to those obtained in field trials under epidemic conditions.

The nature of this resistance is being investigated.

(*c*) *Early Blight Resistance in Tomatoes.*—Early blight caused by the fungus *Alternaria solani* is the most important defoliating disease of tomatoes occurring in Australia. A testing method which measured the inherent reaction of the plants as distinct from the field reaction failed to locate any resistance to defoliation in 113 varieties of *Lycopersicon esculentum* and 39 lines of *L. pimpinellifolium, L. peruvianum,* and *L. hirsutum.* Strains of the fungus differing in pathogenicity were isolated, and these strains were found to be capable of attacking both tomatoes and potatoes.

(*d*) *Angular Leaf Spot Resistance in Beans.*—Angular leaf spot of beans (*P. vulgaris*) is regarded as the most important disease occurring in seed crops in the South Coast area of New South Wales. A search for resistance in 164 lines of beans showed that a very high degree of resistance existed in some of the runner and navy bean varieties, although complete immunity was not found. Certain of these lines are also resistant to halo blight (*Pseudomonas phaseolicola*), anthracnose (*Colletotricum lindemuthianium*), and root-knot nematode (*Heterodera marioni*), so that a carefully planned and executed breeding programme should be able to develop a dwarf green pod bean variety resistant to several or all of those diseases.

(*e*) *Resistance to Root-knot Nematode of Tomatoes.*—Root-knot nematode (*Heterodera marioni*) causes considerable losses in tomato crops grown in hot areas with sandy soils. At Mildura it has been demonstrated that this disease can be controlled in the field by soil fumigation, but as this method is costly, the development of resistant varieties would be of distinct advantage. Preliminary observations have indicated that a line of tomato received from the Hawaiian Experiment Station is resistant to root-knot nematode. Work is in progress to determine to what extent this resistance is heritable and whether this character can be combined with other desirable features like *Fusarium* wilt resistance.

(*f*) *Disease Resistance in Peas.*—It was found that the resistance to *Ascochyta pisi* of the pea hybrids developed from Austrian Winter was not as effective in old plants. Accordingly, an experiment on this aspect was done using Austrian Winter, Greenfeast, and William Massey. These three varieties were subjected to spray inoculation at fortnightly periods and it was found that susceptibility increased with increasing physiological maturity. At the conclusion of the experiment Austrian Winter was still markedly less susceptible than the other two varieties.

No variety of peas has been found with any degree of resistance to bacterial blight (*Pseudomonas pisi*). Manifestation of symptoms of bacterial blight was influenced by soil moisture conditions and exposure to low temperatures. Severe symptoms followed waterlogging, and in general the higher the moisture content of the soil the more severe the symptoms.

## 21. FERTILIZER EXPERIMENTS IN PINE PLANTATIONS.

Preliminary results from a recently begun experiment in newly planted *Pinus caribaea* at Woodburn, on the South Coast of New South Wales, suggest that pine seedlings respond more rapidly to phosphatic fertilizer concentrated on a small area around each tree, than to an equivalent amount per acre broadcast over the whole area. Later observations may show that broadcast treatments are better in the long run. This is certainly so in plantings treated five years or more after establishment.

## 22. MINERAL NUTRITION OF PLANTS IN THE NINETY-MILE PLAIN, SOUTH AUSTRALIA.

Investigation of the mineral nutrition of plants grown in the soils of the Ninety-mile Plain, South Australia, which has been undertaken within the Division of Biochemistry and General Nutrition, has been continued.

The earlier reports of this investigation stimulated an interest in the poor soils of the region, and very extensive areas of several soil types occurring in this deficient terrain are now being sown with improved pasture in the manner found to be effective on the Laffer sand, the first soil type to be investigated. This Division is keeping in close touch with the development, but detailed experimental work is at present being confined to the deep sands that carry a heath vegetation and to heavier soil, known as the Buckingham sand, that carries mallee and broombush.

Cereal cover crops are employed during the establishment of pasture in some of the sandy soils, but these crops grow so poorly in Buckingham sand that their use is not warranted. The very low yield of these crops grown in Buckingham sand is now known to be due to nitrogen deficiency. However, this deficiency may be made good by subterranean clover, which grows extremely well in this soil if appropriately treated. A selection of large-seeded legumes was grown in experimental areas in 1949, for the purpose of estimating their value as an alternative to the cereals employed as cover crops or as crops to be sown on the virgin terrain prior to the establishment of pasture. The growth of certain of these large-seeded legumes was very good, and a wide range of species and selections of *Pisum, Vicia, Lupinus,* and *Lathyrus* is now under observation. The most promising of these will be selected for use in detailed experimental work, prior to recommendations being made for their adoption.

Well-defined symptoms of zinc deficiency have been observed in subterranean clover grown in some of the sandy soils. In other soils, where the deficiency is less acute, the plants may show no visible evidence of zinc deficiency other than a reduction in yield. Preliminary investigations indicate that it may be possible to detect incipient zinc deficiency in the plants by a determination of the concentration of zinc in the leaf and petiole. There is some indication also that analysis of leaf and petiole may be a means of detecting incipient copper deficiency in subterranean clover, of which the only visible evidence may be a lowered seed production.

The ecological survey to which reference was made in the last Annual Report (p.28) has been completed, and a detailed report is being prepared. Climatic and geologic relationships have been elucidated in addition to soil and vegetation studies. Numerous land traverses and two days of aerial reconnaissance were made over the remainder of the Ninety-mile Plain in the course of establishing the affinities of the area surveyed. This has established that the Ninety-mile Plain and the Big and Little Deserts of Victoria are not a homogeneous unit, but consist of a number of topographic-soil-vegetation suites. A detailed vegetation map covering an area of approximately 1,000 square miles has been prepared with the help of aerial photographs supplied by the Royal Australian Air Force. This map also affords a close guide to soil type and land use. In addition, a generalized vegetation map has been prepared covering the area between the Adelaide-Melbourne and Pinnaroo railway lines, and extending approximately 30 miles into the Big Desert in Victoria.

### 23. INFLUENCE OF RAINFALL ON WHEAT YIELD IN SOUTH AUSTRALIA.

In the previous Report, mention was made of the Mathematical Statistics Section's work on yield trends of wheat in South Australia. A necessary preliminary to the investigation of these was the elimination of the effects of rainfall, and this process led to the accumulation of much information on the relationship between rainfall and yield.

These data have subsequently been examined, for the period 1896-1941, and the analysis extends to practically the entire wheat belt of the State, all major soil groups and variants of climatic conditions within the area being represented. Yield was assessed using the hundred, which has an average area of approximately 118 square miles, as the basic territorial unit. The quantitative effects of autumn, winter and spring rains on yield have been determined and related to soil type and general cropping practices in each district. The response of yield to rainfall, when considered as a function of time, takes a mathematically simple parabolic form with a maximum in winter and zeros in autumn and spring or early summer, and provides a clear demonstration of the sub-optimal character of average seasonal rainfall over the greater part of the season and almost throughout the wheat belt.

The results obtained indicate that when, after a few more years' data have been accumulated, the effects of rainfall can be assessed more accurately, it should be possible to make accurate forecasts of yield in the South Australian wheat belt, to the benefit of trade and administration.

## IV. IRRIGATION.

### 1. GENERAL.

Whilst the Organization undertakes *ad hoc* irrigation studies from time to time in a number of localities within the Commonwealth, its most important work in this field is carried out at two irrigation research stations situated at Merbein, Victoria, and Griffith, New South Wales. The Commonwealth Research Station (Murray Irrigation Areas) at Merbein is concerned with problems of interest to growers on the irrigated horticultural lands of the middle and lower Murray, and particularly with the cultivation and processing of grapes. The Irrigation Research Station (Murrumbidgee Irrigation Areas) at Griffith is, apart from its studies directly on irrigation and soil salting, concentrating on problems of the development and nutrient requirements of various crops under irrigation, especially oranges and vegetables.

During the year irrigation studies were made also at Deniliquin, New South Wales, Ayr, Queensland, and the Kimberley Research Station, Western Australia, and the water requirements of tobacco plants were studied at Clare, Queensland (*see* Chapter III., Sections 5, 10, 14, and 18 respectively).

### 2. COMMONWEALTH RESEARCH STATION (MURRAY IRRIGATION AREAS), MERBEIN, VICTORIA.

The Merbein Station is situated in the Mildura district, which comprises the settlements of Mildura, Red Cliffs, and Merbein in Victoria, and Curlwaa and Coomealla in New South Wales. It has concentrated on problems of interest to growers of the middle and lower Murray and an area extending from Swan Hill, Victoria, to the Renmark district in South Australia, about 250 miles distant. Its work includes studies of irrigation methods, soil preservation and reclamation, cultivation and prevention of disease of the major plantings (vines, citrus, and vegetables), and fruit processing. Financial assistance for this work, which has been quite large for over twenty years and was recently increased, is received from a number of bodies, including the Australian Dried Fruits Control Board, the Mildura Packers' Association, the Lands Department of South Australia, and the Renmark Irrigation Trust.

The dried grape crop is the chief factor in the prosperity of these areas and they are at present suffering from the effects of a succession of poor seasons. The yield for the 1949-50 season, as indicated by an examination of the buds, seemed likely to be very high, and when harvesting began in early February a record crop was in sight. During February and March, however, the Mildura district experienced a record rainfall of over eight inches, and exceptionally heavy rainfall occurred in all the dried fruit areas. The result was a 40 per cent. reduction in crop, poor fruit quality, and increased harvesting costs. The Merbein Station has accordingly concentrated on the immediate problems of reducing wastage and readjusting processing methods.

(*a*) *Soil Preservation and Reclamation.*—The history of irrigation in Australia and other parts of the world emphasizes the importance of reclamation and soil preservation work in maintaining fertility in irrigated land.

The possibility of draining the river-deposited soils of the Murray areas by pumping from underlying sand has been further investigated during the past year. In the Renmark Irrigation Area it was shown that pumping from a bore 80 feet deep affected the pressure levels over an area of approximately 200 acres, and that the water-table levels closely followed the pressure levels. An exploratory bore sunk about 80 chains from the present bore showed that the same strata were present to 80 feet, but that the relative thicknesses of comparable strata varied.

During the year the Station co-operated with the First Mildura Irrigation Trust in examining the site where new pumping installations were planned. Boring and a pump test showed the underlying strata to be more uniform and more permeable than those about the present Renmark bore. Water-table as well as pressure levels were again followed in the Mildura pump test, but the relation between the two was not as close as at Renmark. This has been attributed to the lack of gypsum in the upper clay strata at Mildura.

Soil-moisture use by vines under cultivation and by under-cover crops was measured during the summer months. Confirmation was obtained of previous work by the Station which indicated that approximately four inches of water was used by the vines between each irrigation. When an average of less than four inches was applied by furrows, a water shortage over part of the area resulted. Vines, plus a cover crop of lucerne which was allowed to flower before each cutting, normally received 12-14 in. at each irrigation.

Soil-moisture sampling has been undertaken on a number of soil types carrying citrus trees and the results, in association with growth studies, are being used for further study of the required irrigation frequency for citrus.

Methods of measuring irrigation water have been further studied. A 12-in. rotor water meter was developed at the Station and several units made available for use on pasture irrigation. These meters, however, will record flows only between one and three cusecs, which limits their use. The design has been passed on to the C.S.I.R.O. Central Experimental Workshops for further consideration, with a view to developing a unit of more precise construction.

Progress has been made in installing a spray unit at the Station, and most of the equipment needed for experimental work to be carried out has been purchased and set up. In addition, the installation of a pipe line for furrow irrigation, domestic water supply, and fire-fighting purposes is proceeding.

Investigations into the drainage of river-flat areas underlain by sand strata have involved the construction of a light boring rig, capable of getting 100 feet of 1-in. piping into the ground, for examination of the strata. The equipment was too light and was found not suitable for extensive operations. Valuable experience, however, was gained in the method of boring by jetting, and more elaborate equipment now being assembled is expected to give better results.

A drainage trial at Curlwaa consisting of pumping from a 6-ft. by 4-ft. shallow well, bedded in sand, was concluded. The size of the unit and the yield of water were both too small to have any significant effect on near-by ground-water levels.

(*b*) *Land Use.*—Soldier settlement on irrigated lands has greatly increased the soil survey work required in these localities, and the Merbein Station has assisted the Division of Soils by surveying small areas. A survey was made of 1,000 acres at Buronga, in New South Wales across the Murray from Mildura, using type descriptions and survey methods similar to those used by the Division of Soils in surveying an adjacent area at Coomealla. At Goodnight, in New South Wales, another area of 600 acres was surveyed, and recommendations for land use in conformity with the soil types were made.

The introduction of rice cropping on the comparatively new irrigation area of Wakool, in Western Riverina, New South Wales, has led to the application of large quantities of water and to prolonged soakage of the soil. The effect on soil salts of the water used on virgin land for rice production was investigated. On Noorong clay loam, irrigation for rice caused a significant downward leaching of soil salts. The irrigation water penetrated to the 3 to 4 ft. soil level and leached out approximately 70 per cent. of the injurious salts from the top two feet of soil.

The effects of using salt-charged water, outfalling from a gravitational drainage main of the Red Cliffs district, are still being studied. Prior to the establishment of the experimental plot, data on the salt content of the soils were obtained. A lucerne cover is now established, and it is planned to re-examine the soil for salt status wherever manifestations of salt injury are noted. The soil is of heavy texture, unsuitable for subsoil drainage.

On a trial for renovation of Woorinen soils of heavy texture by various pasture mixtures, ameliorants such as sulphur and gypsum were found to improve the soils, the ameliorants being applied with a crop of millet in the first year. A range of pastures subsequently sown showed good growth, but some damage has resulted from heavy rains in late summer. After several years under pasture or fodder crops, horticultural crops will be raised in order to measure the degree of soil renovation effected by this treatment.

Trials of ameliorants on two failing vineyards have also been laid down, with flood substituted for furrow irrigation. At their first harvest the vines showed an improvement with both gypsum and sulphur.

At Bungunyah, New South Wales, gypsum on vines gave a very slight increase in yield when applied to heavy soils; but on the light-textured soils of the Research Station, no increase was noted, possibly owing to a season of abundant crop.

(*c*) *Horticulture.*—Studies on the variation in fruitfulness of the sultana have been continued. The high fruitfulness found in May, 1949, was confirmed in spring after bud burst, when a high proportion of fruitful shoots developed. It seemed probable that a record crop would be obtained, but frequent rains during the harvesting period caused considerable damage. This year the percentage of fruitful buds is much lower and the potential crop for the 1951 harvest is below average. Areas on three district vineyards have been selected for a more intensive study of the problem. Bud study work has advanced to the stage at which some producers have modified vine pruning in accordance with the yield potentialities disclosed by examining dormant buds.

To investigate the apparent preferential bursting of fruitful buds found in 1948-49, bud burst was followed in detail on 81 vines in the spring of 1949. The vines were examined daily during the bursting period. At harvest all bunches were weighed individually, and in autumn the length of all shoots was measured. A definite tendency was found for the fruitful shoots to emerge before the barren shoots.

In studying the nutrition of the bunch it was found that cutting off the portion of the shoot beyond the bunch, and removing the leaves below it, did not materially affect its maturation, indicating that the nutrition of the bunch can be provided by other parts of the vine as well as by the shoot on which the bunch is borne. Only one shoot per vine was so treated.

Disbunching in spring is known to increase the potentialities of the crop for the following season. A trial has been commenced to determine the stage of vine growth at which disbunching is most effective.

The trial on Zante currant vines to compare 2, 4-D sprays with cincturing as aids to fruit setting was continued. This season the yields from the sprayed and the cinctured plots were similar in both fresh weight and dried weight, and about 50 per cent. in fresh weight and 35 per cent. in dried weight greater than that from the untreated plots. Moreover, fruits from the sprayed and the cinctured plots were indistinguishable in quality. Spraying and cincturing together gave a greater fresh weight yield than either separately, but not a greater dried weight.

Early last spring many vines in the Mildura district showed delayed bud burst and restricted growth of some shoots for a few weeks. Later, the vines appeared to overcome this delayed growth, and in most cases there was no appreciable economic loss. In only one vineyard was loss of crop reported, when bunches withered owing to severe growth restriction. The occurrence of deformed basal leaves, with the fact that the vines eventually resumed normal growth, suggested the presence of mites, although none could be found. Trials will be carried out using lime sulphur to combat mites, and samples of canes are being examined by the Division of Entomology.

Towards the end of the sultana harvesting period, downy mildew appeared in a number of vineyards, and caused premature defoliation of the vines. Routine spraying with copper fungicides next season should prevent any severe outbreak.

Measurement of the chloride content of the sultana vine on various soil types is continuing. Leaves, canes, and trunks are being examined to determine the relation of their salt contents to that of the soil. Results show that random sampling of the middle leaves of the growing shoot gives a reliable figure for the chlorine status of any vine at a particular time. Also there is a general accumulation of chlorine in the leaves during the growing season. The chloride figures correspond well with the visible salt damage on the leaves and with the general vigour of the vine.

Monthly samples of sultana leaves taken from the plots of a manurial experiment on the Station vineyard showed an accumulation of boron in the leaves as the season progressed. No correlation between boron content and the application of any particular fertilizer could be demonstrated. The boron content of sultana vines and of citrus trees growing on different soil types in the Mildura district was also examined. The symptoms of boron excess in sultana leaves were identified as brown necrotic spots, appearing first around the margins of the leaves and then spreading into the interveinal areas. Analyses suggest that the threshold values for appearance of such symptoms may be of the order of 200 p.p.m. boron.

Investigations have shown that the boron content of Murray River water at Mildura is normally very low, but that the drainage water from Mallee-type soils which have a high boron content frequently contains large amounts. Average figures for some of the main drains in the district are approximately 3-4 p.p.m. of boron.

Regular weekly measurements of fruit circumference have been carried out on Valencia oranges in several Merbein citrus orchards during the current growing season. It is planned to correlate the growth curves so obtained with soil moisture determinations, to determine the adequacy of the present irrigation system is promoting citrus growth.

Numerous observations and measurements on the growth of citrus shoots have been made, and a paper describing the types of shoots involved and their role in the growth of trees and production of fruit is being prepared for publication.

It has been found possible to control hardhead (*Centaurea picris*) with "Hormex". The weedicides tried previously — power kerosene, "Atlacide", "Methoxone", and an oil-phenol mixture—were not successful. Early in September, 1948, weeds on uncultivated land were sprayed with a 0.5 per cent. solution of "Hormex". Several small spot sprays were applied during the season when a few new plants and a little regrowth appeared. In 1949-50 no spraying was carried out and practically no growth has occurred.

This season "Hormex" was tested on hardhead in a vineyard. Two strengths were used—0.5 and 0.3 per cent.—and the spray was applied on 17th October. When sprayed, the weeds were either upright and unbranched or in the rosette stage. They were left uncultivated for several weeks after spraying. On 7th November most of the plants appeared to be dying, and those that seemed unaffected were resprayed. Normal cultural practice was carried out from mid-November onwards, and at the end of the season there were only a few plants in each plot. The full effect of the spray will not be known until next season.

Another more extensive area of uncultivated land was also sprayed this season. "Hormex" at 0.18 and 0.5 per cent. and "Weedone" at 0.2 and 0.5 per cent. all killed the tops of the weeds, and practically no regrowth occurred. It would appear, therefore, that both the triethanolamine salt and the ethyl ester of 2, 4-D are effective, and next season it is hoped to test some 2, 4, 5-T preparations.

Effective control of hoary cress (*Lepidium draba*) can be obtained by the use of the hormone weedkillers "Methoxone" and "Hormex". No regrowth was evident this season on plots sprayed in the 1948-49 season.

An attempt was made to control bindweed (*Convolvulus arvensis*) in a vineyard. "Hormex" at 0.14 and 0.28 per cent. was used. The land was left uncultivated from early September to mid-November and spraying was carried out on 17th October. A second light spraying was necessary for a few plants. The weaker spray seemed less effective, and in both plots a few plants were growing weakly later in the season. A good measure of control was obtained, however, and it will be interesting to see what growth of bindweed occurs on these plots next spring.

The above-ground parts of camel thorn (*Alhagi camelorum*) can be killed with kerosene, oil and phenol, "Atlacide", "Methoxone", "Hormex", and "Weedone", but regrowth from the vigorous root system has not so far been prevented. It is hoped to test 2, 4, 5-T preparations against this weed next season.

(*d*) *Plant Nutrients.*—Field trials with commercial fertilizers have experienced a succession of unfavorable seasons in which yield losses have tended to mask the results. General results show yield increases due to nitrogenous fertilizers, except at Woorinen, where soil alteration has affected the result.

In the past season, impending wastage of the grapes necessitated the recording of yield results as fresh grapes, from which dried fruit yields were calculated on the basis of the Baumé readings.

Applications of zinc sulphate as a swab to the pruning cuts of Gordo vines also gave inconclusive results owing to crop damage.

A number of plots containing indicator plants which may indicate micro-element deficiencies or excesses have been established throughout the district on the major soil types. The indicator plants comprise flax, wheat, oats, rye, cabbage, cauliflower, and onions, to which beans, cotton, sugar beet, and maize will be added as spring sowings. These plants react to certain soil deficiencies and excesses by developing symptoms which are readily recognized, and are under continuous observation for this purpose.

Further work has been carried out on the influence of zinc on seed formation, berry development, and yield in the Gordo blanco grape. It has been shown that on the sites chosen for investigation, the swabbing of pruning cuts with a concentrated zinc solution favoured seed formation, resulted in more uniform berry development, and reduced the proportion of berries having no mature seeds, both where there was an increase in yield and where there was none. Zinc deficiency has been shown to be one of the factors contributing to the poor setting, uneven development, and declining size of the Gordo grape on some sites in the Mildura district.

It is proposed to carry out a chemical survey of vines in the Mildura district to determine their zinc status, and preliminary work on methods of analysis is in progress.

Laboratory trials on the effect of leaching on ammonium sulphate fertilizers indicated that with an irrigation of 30 inches, only a small quantity of ammonia was leached through two feet of soil. The bulk of the added ammonia was fixed in the top three inches when the ammonium sulphate was applied to the surface. Nitrates, on the other hand, are readily leached.

Soil incubation tests carried out in the laboratory showed that a dressing of 3 cwt. per acre of sulphate of ammonia had the bulk of its ammonia converted to nitrate in approximately 21 days.

Added chloride to 100 p.p.m. had a depressing effect on nitrification under similar conditions.

(*e*) *Fruit Processing.*—Work on the drying of sultanas has included studies of—(i) suitability of sulphonated fatty acid esters for use in oil emulsions in the cold process; (ii) effect of treatment with sulphur dioxide prior to cold dipping; (iii) use of fungicides to prevent spoilage of fruit during drying; (iv) modifications to bulk hot dipping procedures; and (v) packing problems. This work is described in detail in Chapter XII., Section 13.

(*f*) *Vegetables.*—In co-operation with officers of the Division of Plant Industry, the Station carried out investigations during the 1949-50 season at Merbein and Red Cliffs, Victoria, and Buronga, New South Wales. The work was mainly confined to field grown and glasshouse tomatoes, soil fumigation with "DD" ("DD" is the trade name of an approximately equal mixture of 1:3 dichloropropene and 1:2 dichloropropane) for the control of root-knot nematode or eelworm (*Heterodera marioni*) in tomatoes, field trials of guar, and commercial trials of a legume new to the district, *Lathyrus ochrus.*

With tomatoes, investigations were continued to develop suitable *Fusarium*-wilt-resistant hybrids for the district. Although some of the hybrids tested under field conditions showed promise, further work appears necessary to develop a variety possessing all the desirable characteristics. With this in view, crosses were made of various varieties and hybrids, and seed obtained for trials next season.

Work was also carried out on tomatoes grown under glasshouse conditions, in an endeavour to develop improved varieties. Several new hybrids were tested and crosses made between suitable varieties and hybrids. Seed was obtained from these crosses for further studies. It is hoped that a variety may be developed which is better than the one now commonly grown, South Australian Dwarf.

Trials on soil fumigation for controlling root-knot nematode on tomatoes, commenced in 1948-49, were continued during the 1949-50 season. The results of the 1948-49 trial have been published, and the data from the 1949-50 trial are being assembled and examined. However, as control of root-knot nematode by soil fumigation appeared to be very expensive, seed of plants which were reported to be resistant to eelworm in Hawaii and to be compatible for crossing purposes with the common tomato (*Lycopersicon esculentum*), were obtained and plants from this seed grown in a badly infected area at Red Cliffs to determine whether they possessed resistance under local conditions. The results were highly satisfactory, and crossing work has commenced. It is hoped that hybrids resistant to eelworm can be developed.

Replicated field trials of guar grown under irrigation conditions were carried out. Data including yield, maturity, germination, and agronomic notes have been obtained and are being examined.

Following small trials of several legumes new to the district, a commercial trial was conducted in 1949-50 at Merbein of one of the most promising varieties, *Lathyrus ochrus.* The results were very satisfactory, the legume maturing earlier than tick beans, which are commonly grown at present. One advantage of this legume is that collection of seed is comparatively simple. Further commercial trials on additional soil types in the Mildura and Woorinen, Victoria, and Renmark, South Australia, districts have begun.

(*g*) *Large-scale District Problems.*—Consideration is given to large-scale district problems by Committees appointed by Commonwealth or State authorities.

The Wakool Land Use Committee has been responsible for field trials designed for investigating the comparative productive values of the major soil types defined by the Division of Soils. Special plots have been established for this purpose, and the observed results published in the Annual Report of the Committee.

The salt and seepage problem of two Victorian irrigation districts, Tyntynder and Cohuna, have received attention. Investigations disclosed wide-spread waterlogging, which has affected production in portions of both areas, particularly in Cohuna. Improvements are being effected by improving irrigation frequency and methods, and maintaining a high standard of plant production. Inquiries are now being made into the possibility of removing the salt-charged subsoil water found in portions of both areas.

The East Murrakool district in New South Wales, north of Barham, and the Lower Murrakool district in New South Wales, north of Swan Hill, have both set up special committees to inquire into the potentialities of these areas for irrigation expansion. The Merbein Station assisted in technical aspects of the inquiry, and reports have been submitted to the River Murray Investigations Committee set up by the New South Wales Government.

### 3. IRRIGATION RESEARCH STATION (MURRUMBIDGEE IRRIGATION AREAS), GRIFFITH, NEW SOUTH WALES.

Work at Griffith has been concentrated mainly on physiological and chemical studies of plants under irrigation when subjected to various manurial and management practices; a study of the physical properties of soils under irrigation; and a detailed study of tree development and yield of oranges under various cultural, irrigation, and fertilizer practices.

(*a*) *Irrigation.*—The most widely adopted method of supplying water to the soil under horticultural conditions is by means of furrow irrigation. In general, there is a considerable margin of excess in the amount of water applied and that actually used or needed by the plants. This excess is in part unavoidable, but is nevertheless wasteful, and endangers the fertility of soils through the building up of water-tables and salting.

Studies have accordingly been continued on the mode of entry of water into soils from furrows of different shapes and sizes, and on the nature of its subsequent movement through the soil to wet the desired zones.

An understanding of fundamental furrow relationships has enabled suggestions to be made for improving irrigation techniques to suit different types of soils and varied surface topography. Special emphasis in these investigations has been given to vegetable irrigation, where the problems of irrigation are encountered in their most acute form. To that end, the effects of varying the spacing of rows and of changing furrow shapes on the quantities of water used have been determined.

(*b*) *Chemical Investigations.*—In irrigated areas, excess salt accumulation in the soil is often a serious problem. Soil-salt accumulation reduces yields and in extreme cases makes the land sterile, so that it has to be abandoned. Studies have, therefore, been made on the accumulation of salt in the leaves of fruit trees and other plants, and in this way a method of diagnosing salt injury has been evolved.

In parts of the Murrumbidgee Irrigation Areas sand drifts have been surcharged with water, leading to dangerous waterlogging of agricultural lands. Studies have been made of the salt content of water pumped from bores tapping these sandbeds. Such studies are important for proper understanding of the groundwater hydrology, and are helpful in devising remedial measures.

(*c*) *Drainage.*—The value of tile drainage for controlling waterlogging and salting is being investigated. Drainability studies to determine the best depth and spacing have been carried out on most soil types liable to waterlogging and salting. Results from these studies have been applied in one farm-size tile drainage trial, where a close watch is being kept on changes in tree health and yield, on the amounts of soluble salts in the soil and drainage water, and on the water-table fluctuations. The drainage system removes considerable quantities of excess water and soluble salts each season, and the effect of this on the plantings is being recorded. A second farm-size drainage trial is proposed.

The possibility of using horticultural farms, abandoned because of salt damage, for growing pastures and fodder crops for dairying purposes was explored. It was found practicable to grow pastures and annual and perennial crops on a light soil type, provided the farm layout was designed to suit the irrigation requirements of the soil type. Good stands of lucerne, winter pasture, and annual crops were grown.

(*d*) *Horticulture*.—The factorial field experiment with oranges, embracing cultural, irrigation, fertilizer, and stock and scion treatments, has continued. The weeds-mown treatment has resulted in a great depression of the health, size, and yield of the trees, and of the quality of the fruit, but increased dressings of frtilizer led to improvement in the health and appearance of the trees. The oil-spray treatment has continued to give greater yields than the other treatments. In view of these results, work on the soil fertility and structure of the various plots is being initiated.

The replanting of old orchard land with fruit trees, without any reconditioning treatment, has been found in practice to give unsatisfactory results. Field experiments embracing several reconditioning treatments were laid down in old peach land and old vine land in 1945. During the progress of the reconditioning period, physical and chemical measurements were made on the soil. In one experiment the treatments have now been discontinued and the area will be planted with peaches in the coming spring, and the effect of the previous treatment on their growth noted. In the other experiment reconditioning will continue for a further period.

Trials of the vertical-axis fan for the frost protection of citrus and deciduous trees have continued. The original design of the fan has been found effective to a limited extent, and certain modifications to the design have been made by the Section of Meteorological Physics (*see* Chapter XXVII., Section 5). The trials of the new design will begin this winter. In addition to the vertical-axis wind machines, a high-powered horizontal-axis machine has been constructed, following the American pattern, and will be tested in a local citrus grove this winter.

(*e*) *Vegetables*.—Investigations are at present centred mainly on the mineral nutrient requirements of the chief vegetable crops on the M.I.A. Three aspects are under consideration—

(i) The capacity of the oil to supply adequate available nitrogen to a crop following a period of fallow.
(ii) The changes in availability of the phosphorus in phosphatic fertilizers when applied to M.I.A. soils.
(iii) The rate of build-up of available phosphorus in the soil, and its possible interaction with the trace elements important in plant nutrition.

The first problem involves a series of field trials with vegetable crops grown at different times of the year and after fallow periods of various lengths. It has been shown in the past that the optimum rate of nitrogenous fertilizer application depends almost entirely on the immediate past treatment of the site. Where no fallow period has been permitted, frequently as much as half a ton of sulphate of ammonia per acre will not satisfy the needs of the crop. On the other hand, a cultivated and irrigated fallow, of which the minimum length and conditions have not yet been defined, can supply the whole of the needs of the crop for nitrogen. Work is proceeding with a view to gaining more information on the rate of nitrification (i.e. the production of available nitrogen) by soil organisms and on the various factors which control it. Ultimately, with this knowledge and by the adoption of appropriate cultural practices, the amount of nitrogen required from fertilizers by annual crops should be substantially reduced.

The second major plant nutrient of importance under M.I.A. conditions is phosphorus. All the soils of the district are naturally deficient in phosphorus, and superphosphate has been extensively used in the past 20 or 30 years. On some fields, so much superphosphate has been added that no benefit is derived from further dressings; on others, the soil is at or near its original level. "Quick" soil tests are being used to correlate values with observed crop response, so that specific recommendations may be possible in the future.

A further complication is introduced when heavy dressings of superphosphate have been given for a number of years. Instances have been found where the excessive phosphorus has immobilized certain of the trace elements, and work has commenced to define the conditions under which "phosphate-induced" deficiencies may occur.

During the past year, two new crops have been grown in order to assess their suitability to the district. Several small plots of cotton, the major one being an irrigation frequency trial, were grown. Growth and setting of "squares" was good, but because of the relatively short growing season, there appears to be scope for some selection of varieties.

Following a successful preliminary trial with soybeans in 1948-49, a second trial was grown, to compare four of the more promising varieties and their fertilizer requirements. Results are not yet to hand.

(*f*) *Plant Physiology*.—The plant physiology section is working on two major problems. The first is concerned with soil fertility as affected by organic manures, and the second with plant-water relations. Both problems, however, are being attacked by established methods of plant-growth analysis.

Much time has had to be spent upon the development of plant-sampling techniques appropriate to field experiments, and this work has now been published in collaboration with an officer of the Section of Mathematical Statistics. Rapid methods for the estimation of leaf area, and for the washing out of root systems from pot cultures, have also received attention.

(i) *Soil Fertility*.—The maintenance of soil fertility is a major issue in irrigation agriculture and while this problem can be and is being investigated by means of field trials and by physical studies of soil structure (*see* below), it was felt that further light could be thrown upon it by a detailed study of the response of crop plants to soil treatments which are known to influence soil fertility and to help maintain a favorable soil structure. To this end, work has been in progress on the effects of organic matter—particularly rice hulls—on the growth and nutrient intake of vegetable crops.

The growth response of tomatoes to rice hulls has been analysed into two phases when this organic amendment is used without added nitrogen. The first phase is one of delayed emergence and depressed growth, and the possibility that this is brought about by a toxic or inhibitory substance produced during the decomposition of the organic matter is being investigated. The second phase is characterized by a stimulus to growth which ultimately gives larger plants and fruit yields than are produced on the untreated control plots. Such a stimulus is apparent from an early stage of growth when nitrogen is added with the rice hulls, and in both cases there is good evidence to show that much of this stimulus to growth is due to an increased intake of phosphorus from the soil.

Although necessarily limited in scope by its detailed character, it is believed that this work is relevant to a wide range of soil fertility problems in which organic matter plays a part.

(ii) *Plant-Water Relations*.—On an irrigation area it is clearly of importance to understand how plants respond to differences in soil moisture content. A detailed study has been made of the effects both of a light and of a severe wilting treatment on the growth of individual leaves of the tomato plant and of the stems and roots. Treatments were given at approximately the eight-leaf stage, and changes in dry weight, water, total nitrogen, protein nitrogen, total phosphorus, and certain phosphorus fractions have already been determined or are about to be investigated.

In connexion with this work, two large pot-culture experiments with tomatoes and one subsidiary one with linseed have been conducted. In the current year, also, an attempt was made to gain confirmation of certain points under field conditions. However, the phenomenal rains of early February destroyed all hope of doing this, and very little information could be salvaged from the experiment.

(*g*) *Soil Physics.*—Investigations are being made on the methods used in measuring the structure of soils. Experience has shown that when virgin land is cultivated and brought under irrigation agriculture, the natural properties of the soil which preserve its structure are destroyed, and the soil is liable to become dense and compacted, making it difficult to irrigate and unsuitable for plant growth. Under non-irrigated conditions soils with poor structure are liable to serious losses by water and wind erosion.

Various cultural treatments, such as the growing of specific soil reconditioning crops or the addition of soil structure amendments, are being used in field experiments to determine the best methods of improving structure where it has deteriorated, or of preventing structure deterioration on new land. Studies are also being made to determine the most favorable structure state for special crops.

Special attention is being given to the mechanical effects of cultivating implements on the soil structure. A shear and compression machine has been designed and built to reproduce these effects in the laboratory, so that our knowledge of the fundamental principles involved in these processes can be extended.

## V. ANIMAL HEALTH AND PRODUCTION.

### 1. General.

Research into problems of animal health and production has continued to form an important part of the Organization's activities. This work is undertaken within the Division of Animal Health and Production, which has its head-quarters in Melbourne, Victoria.

*Division of Animal Health and Production.*—The major activities of the Division have been concerned with problems in the sheep and cattle industries. The results of this work for the year under review are briefly described in Chapter VII., Sections 2, 3, 5-7, 9, and 12-19, and Chapter VIII. The programme of work within the laboratories and the field stations of the Division is outlined in this chapter.

Co-operative work with other Divisions and with some of the Departments of Agriculture and Universities in the several States has continued to play an important part in the work of the Division.

### 2. Animal Health Research Laboratory, Melbourne.

(*a*) *Pleuropneumonia of Cattle.*—Research has continued on this disease and vaccine has been produced for use in the industry (*see* Chapter VIII., Section 2 (*a*)).

(*b*) *Tuberculosis of Cattle.*—Research has been restricted owing to the pressure of other work (*see* Chapter VIII., Section 2 (*b*)).

(*c*) *Mastitis in Dairy Cattle.*—Research has continued on this disease (*see* Chapter VIII., Section 2 (*c*)).

(*d*) *Haematuria vesicalis.*—Research has continued in the laboratory on this problem (*see* Chapter VIII., Section 2 (*e*)).

(*e*) *Anaplasma centrale.*—The strain has been maintained and supplied to the Department of Agriculture and Stock, Queensland. Infective blood kept at about −80° C. has produced typical infection after 739 days at this low temperature.

(*f*) *Brucellosis of Cattle.*—Intensive study has continued on the immunizing value of Strain 19 *Br. abortus* and on the natural disease (*see* Chapter VIII., Section 2 (*d*)).

(*g*) *Physiology of Milk Production.*—Work was begun on an investigation of the effects on milk secretion and production of pressure from milk accumulation in the mammary gland. Identical twins were acquired to build up a small herd for this investigation.

(*h*) *Caseous Lymphadenitis of Sheep.*—The experiments on the protective value of annual vaccination one month before the sheep are shorn were continued (*see* Chapter VII., Section 15 (*a*)).

(*i*) *Toxaemic Jaundice of Sheep.*—The co-operative investigation on heliotrope poisoning and chronic copper poisoning of sheep has been continued (*see* Chapter VII., Section 15 (*b*)).

(*j*) *Toxicity of Wheat for Stock.*—The experiments have been continued (*see* Chapter VII., Section 7).

(*k*) *Physiology of Reproduction in Sheep.*—Research on several aspects of the physiology of reproduction in sheep has been continued (*see* Chapter VII., Section 12).

(*l*) *Microbiological Chemistry.*—A new section of work was started on problems of microbiological chemistry arising in the several major investigations being carried out in the laboratory. The preliminary period was spent in the assembling of apparatus. A start was made on the study of the nutrition of a strain of *Lactobacillus* isolated from horses suffering intoxication from wheat.

### 3. McMaster Animal Health Laboratory, Sydney.

(*a*) *Parasitological Investigations on Internal Parasites.*—Studies on anthelmintics and on resistance and immunity to nematode (worm) infestations including serological investigations, were continued; others on the survival of eggs and larvae were commenced (*see* Chapter VII., Section 16).

(*b*) *External Parasites of Sheep.*—Further observations were made on the control of the foot louse of sheep *Linognathus pedalis.* A series of small-scale trials was conducted on the possible value of insecticidal "fogs" for the control of external parasites (*see* Chapter VII., Section 17).

(*c*) *Blowfly Strike Problem.*—Some preliminary investigations were made on the possible use of insecticidal fogs, sprays, and jets, for prevention of body-strike (*see* Chapter VII., Section 18).

(*d*) *Parasite Physiology and Toxicology.*—Work in this field has continued and four main studies have been carried out. They are of a fundamental or academic nature, but for the sake of convenience are briefly reviewed in Chapter VII., Section 16.

(*e*) *Nutrition Studies.*—Studies have been continued on: (i) the feeding management of sheep in the winter in Tasmania, (ii) methods of feeding sheep for maintenance under drought conditions, (iii) the effect of nutrition on the breeding performance of Merino ewes, (iv) stall-feeding of beef cattle, and (v) seasonal changes in the nutritive value of pastures (*see* Chapter VII., Sections 6, 9, and 12, and Chapter VIII., Section 6 (*d*)).

(*f*) *Biochemical Studies.*—Work on the carbohydrate metabolism in ruminants was continued and extended.

Studies were also made on the biochemical processes in the rumen (*see* Chapter VI., Section 3). The determination of blood inorganic phosphate levels and the metabolism of oxalates in sheep were also studied.

(*g*) *Physiology of Reproduction.*—The process of fertilization in the ovum of the rat has been studied in detail. The time relationships of the several processes occurring between penetration of the sperm and the first division of the egg have been established. Many attempts have already been made by scientists working in this field to fertilize the ovum *in vitro,* but so far without success. The results obtained from these investigations suggest that the sperm must reside for about three hours in the uterus or Fallopian tube before it can penetrate the egg. The reasons for this are being sought.

(*h*) *Inactivation of Gonadotrophin.*—The resignation of the officer who was carrying out these studies brought them to an end.

(*i*) *Section of Mathematical Statistics.*—The officers of the Section attached to the Division continued to be housed at the McMaster Laboratory. Assistance was given in the preparation of detailed plans and in the computation of results from experiments, especially the sheep strain trials, sheep-breeding trials, and beef carcass definition.

### 4. VETERINARY PARASITOLOGY LABORATORY, QUEENSLAND.

This laboratory, established in 1948 as a Section in the Division of Animal Health and Production, is located at Yeerongpilly, Queensland, in buildings leased from the Queensland Department of Agriculture and Stock. Officers of the Division of Entomology are accommodated there. Co-operative work between the two Divisions and the Queensland Department of Agriculture and Stock is being carried out, and the co-ordination of the research programmes is assisted by the Joint Veterinary Parasitology Committee (Queensland). The research programme, carried out mainly by the Division of Animal Health and Production, has included the following studies.

(*a*) *Epidemiology of Parasitic Gastro-enteritis of Cattle.*—These studies have been carried out in co-operation with the Queensland Department of Agriculture and Stock (*see* Chapter VIII., Section 3 (*a*)).

(*b*) *Faecal Examination as a Measure of Helminth Infestation in Cattle.*—Progress has been made in establishing the technique and standards for measuring the degree of infestation (*see* Chapter VIII., Section 3 (*b*)).

(*c*) *Studies on Liver Fluke and Hydatid Disease of Cattle in Queensland.*—The epidemiology and economic importance of these diseases in cattle have been studied (*see* Chapter VIII., Section 3 (*c*)).

(*d*) *Studies on Paramphistome Flukes in Cattle.*—Studies have been made on the identification, life cycle, economic importance, and control of species of stomach fluke in cattle (*see* Chapter VIII., Section 3 (*d*)).

(*e*) *Studies on Methods of Administration of Anthelmintics to Cattle.*—Physiological studies were started to develop methods by which the passage of anthelmintics into the true stomach of cattle could be brought under control (*see* Chapter VIII., Section 3 (*e*)).

(*f*) *Worm Nodules* (Onchocerca gibsoni) *in Cattle.*—Studies on this problem have been delayed pending the provision of an insectary.

(*g*) *Anthelmintic Treatment of Calves.*—Studies on the treatment of hookworm infestations in calves were carried out (*see* Chapter VIII., Section 3 (*f*)).

(*h*) *Control of Body Strike in Sheep.*—In co-operation with the Division of Entomology, field trials with DDT and BHC for the control of body strike in sheep were carried out (*see* Chapter VII., Section 18).

(*i*) *Studies on "Queensland Itch" and Onchocerciasis of the Horse.*—The results of the work have shown that "Queensland itch" is not associated with skin infestation by microfilariae of *O. cervicalis.* Larvae have been seen in the skin of horses with and without lesions of "Queensland itch". Of horses examined, 20 per cent. were affected with the disease, whereas the larvae could be found in 80 per cent. The lesions of the disease strongly suggest hypersensitivity as a cause. Night-biting insects, such as Culicoides, may be responsible. Intradermal tests with an antigen prepared from dry Culicoides have given extensive reactions in affected animals. Blood histamine estimations have shown minimal values at 3 p.m. and maximal values at 9 p.m. Considerable information has been collected on the species of Culicoides present in south-east Queensland. Several thousand specimens have been examined for filariid larvae; an infection rate of one per cent. has been found in one species but larvae have not been found in four other species.

### 5. F. D. MCMASTER FIELD STATION, BADGERY'S CREEK, NEW SOUTH WALES.

The work of the Station has been largely devoted to breeding studies on sheep and to the development of hybrid dairy cattle based on Zebu crosses with British breeds.

(*a*) *Study of Inbred Flocks of Australian Merinos.*—*See* Chapter VII., Section 13 (*a*).

(*b*) *Study of Polledness in Sheep.*—*See* Chapter VII., Section 13 (*c*).

(*c*) *Study of the Inheritance of Component Fleece Characteristics.*—*See* Chapter VII., Section 13 (*d*).

(*d*) *Study of the Inheritance of "Hairiness" and of "Fluffy-tip".*—*See* Chapter VII., Section 13 (*e*).

(*e*) *Studies on Fleece Rot.*—Owing to the high incidence of "fleece rot" in the sheep due to excessive rains during the last two summers, a study of probable associations has been made (*see* Chapter VII., Section 15 (*d*).

(*f*) *Study of Hybrid Dairy Herd.*—Work has been continued on the development of a herd of hybrid dairy cattle (*see* Chapter VIII., Section 5).

### 6. WOOL BIOLOGY SECTION, SYDNEY.

(*a*) *Comparative Studies of Breeds of Sheep: An Experimental Study.*—The experiment to study Merino, Corriedale, Polwarth, and Lincoln breeds on a standard ration with unrestricted intakes was continued (*see* Chapter VII., Section 14 (*a*)).

(*b*) *Comparative Studies of Breeds of Sheep: Field Studies of Skin and Fleece.*—*See* Chapter VII., Section 14 (*b*).

(*c*) *Comparative Studies of Breeds of Sheep: Chemical Study of the Fleece of Merino and Corriedale Sheep under Experimental Conditions.*—*See* Chapter VII., Section 14 (*c*).

(*d*) *An Analysis of Skin and Fleece Characters in Ewe Progeny of Top Sires in an Australian Merino Stud.*—*See* Chapter VII., Section 14.

### 7. REGIONAL PASTORAL CENTRE AND LABORATORY, ARMIDALE, NEW SOUTH WALES.

This Regional Centre was established in 1947-48 for co-operative work between several Divisions of the Organization and the Department of Agriculture of New South Wales. The development of the work has been hampered by the lack of progress in the establishment of laboratory and housing facilities. The following programme of research has been carried out by the Division of Animal Health and Production during the year:—

(*a*) *Field Investigations of the Control of Body Strike in Sheep.*—*See* Chapter VII., Section 18 (*a*).

(*b*) *Blowfly Strike in Sheep—Studies on Lamb-marking Dressings.—See* Chapter VII., Section 18 (*b*).

(*c*) *Study of Strains of Merino Sheep in Several Environments.*—The environment of Chiswick Field Station is being used as one of the several environments for the study (*see* Chapter VII., Section 13 (*g*)).

(*d*) *Studies on Neo-natal Mortality in Lambs.—See* Chapter VII., Section 19 (*a*).

(*e*) *The Effects of Grazing Management on Pasture and Animal Production.*—A co-operative investigation is being carried out with the Division of Plant Industry on the effects of different rates of stocking, with and without rotational grazing, on the health and production of the animal and of the pasture (*see* Chapter III., Section 6 (*a*)).

(*f*) *Internal Parasites in Sheep.*—Studies have continued on the epidemiology of worm infestations of sheep and related subjects (*see* Chapter VII., Section 16).

(*g*) *Winter Feeding of Weaners.—See* Chapter VII., Section 16 (*d*).

(*h*) *Studies on Animal Behaviour.*—A series of observations on animal behaviour was started. Observations were made on the distance travelled by sheep grazing a pasture on a rotation system or continuously, and in paddocks of different sizes; the variation in intensity of grazing in a paddock; the periods of time spent grazing, idling, and resting by groups of sheep in paddocks of different sizes. All these and other observations are being made to determine the influence of behaviour on the productivity of the sheep and of the pasture.

### 8. NATIONAL FIELD STATION, "GILRUTH PLAINS", QUEENSLAND.

The rainfall for eleven months to the end of May, 1950, was 21.90 inches, which is well above the average. For the third successive year excellent conditions have, for the most part, been experienced. Severe frosts in July, 1949, caused almost complete destruction of the annual and perennial grasses on the open country. The rainfall in September was 1.55 inches, and in October 3.07 inches. The response of the pastures was not good, as the temperatures were still too low, but a widespread germination of bluegrass, *Dichanthium sericum,* occurred on the plain country. The chief response from the late summer and autumn rains was again from the bluegrass, which became dominant over the whole of the plain country.

The good seasons have led to good regeneration of mulga in the timbered country; seedlings have grown well and mature trees have increased their foliage. The grass species, however, have become rank and an attempt to control this by allowing cattle to graze has not been fully successful.

The health of the sheep has been good but with the higher rainfall of the last three years the incidence of the foot louse and the body louse has increased in the district and these parasites have been found on the Station for the first time. Fly strike has been unusually severe in the district but little trouble was experienced in the sheep on the Station; the protective measures proved effective.

In spite of the good season and a low rate of stocking the cut of greasy wool per head was surprisingly light. However, the yield was high in all the batches from the several flocks.

The investigational work has continued and the sheep-breeding projects now absorb most of the facilities of the Station. The two principal projects are (i) the breeding systems investigation and (ii) the strain trial (*see* Chapter VII., Section 13 (*g*)). Owing to the limited staff and facilities the top-cross trial was placed in abeyance for a period of a year.

Results cannot be obtained from the breeding investigations until several generations have been produced, but interesting and valuable information has been obtained on the reproduction of sheep of several ages and on growth rates and wool production.

Problems in animal health and in husbandry are incidental to the main research programme. The loss of lambs between mothering and marking has fluctuated between 10 and 20 per cent. during the last three years. The cause is unknown but is under investigation.

In addition to the work of the Division of Animal Health and Production at the National Field Station, the Division of Plant Industry has been carrying out grazing management studies on Mitchell grass pasture, pasture regeneration studies, and a general study of the vegetation on the Station (*see* Chapter III., Section 8).

### 9. FLEECE ANALYSIS LABORATORY, CHESTER HILL, NEW SOUTH WALES.

This laboratory was established in order to carry out the large number of physical measurements on the fleece of sheep required in the experimental biological work of the Division and to develop new methods giving greater speed and greater accuracy.

During the year, 23,341 measurements were made which included 4,965 scouring tests, 6,882 measurements of mean diameter, 4,409 determinations of density of fibre population, and 4,300 measurements of crimp and staple length. The techniques remained basically the same as for the previous year but with the increased experience of the staff the measurements became more reliable.

Investigational work was continued during the year. Progress was made in the development of the fibre-length analyses. It was shown that if the staple was dried at 130° C. and then quickly immersed in medicinal paraffin, the extension of the fibres before breaking was only 3 per cent. An improved electronic pulse-gate was devised during the progress of this work. An investigation was carried out on the effect of regain of the wool on the apparent diameter of the fibre as measured in the cast. It was found that the diameter as measured by the cast corresponds to that of wool conditioned at about 80 per cent. relative humidity. It was found that cutting and polishing the cast ends of the fibres splayed the ends and thus produced an increase in diameter of about 10 per cent. Further work was done to check the accuracy of the mid-side sample for the estimation of yield of the whole fleece. A correlation of 0.7 between the mid-side and whole-fleece yield was found.

### 10. POULTRY RESEARCH CENTRE, WERRIBEE, VICTORIA.

Progress has been made in the development of the Poultry Research Centre at the Division's Field Station, Werribee, Victoria. The experimental flock has been increased. On 1st May, 1950, the numbers were 2,679 female and 261 male birds. The programme of research work has remained unaltered and steady progress is being made.

(*a*) *Investigation of Breeding Systems.*—Fifteen separate breeding flocks have been established. The fourth generation was hatched in 1949 and commenced laying early in 1950. Comparison of egg production, on the survivor basis, of the several breeding groups with that of a control group showed that one family only, founded on superior dams, had a better performance, which was highly significant. Two other groups gave a better performance at the 5 per cent. significance level than the control group. On the basis of mortality, three groups were superior at a highly significant level. The records of pullets of simple crosses between Leghorn and Australorp again showed the expected hybrid vigour. Fertility and hatchability were also better in the crossbreds.

(*b*) *Physiology of Reproduction: Inheritance of Fecundity.*—The technique of artificial insemination has been further improved. Work on the metabolism of fowl sperm yielded results which promise well in the development of a technique for the dilution and storage of sperm. The important role played by fructose was shown. Studies on the cause of infertility in the female were started.

(*c*) *Biometrical Methods for Measuring Performance.*—Progress was made in the statistical studies for the analysis of the breeding records. Minimal numbers required for progeny testing and the period for the measurement of annual production were established. A formula was developed for the correction of hatching date. Also a system was developed to obtain reliable mean egg weights.

(*d*) *Inheritance of Characters.*—An analysis of shank colour inheritance in 96 birds from several degrees of crossing between Leghorn and Australorp breeds suggested the presence of three autosomal and two sex-linked genes as responsible for shank colour.

(*e*) *The Effect of Synthetic Oestrogen on Cockerels.*—Three experiments were carried out on 141 cockerels to determine the effect of synthetic oestrogen on cockerels. The results did not favour the use of the hormone for fattening cockerels under marketing conditions in Australia.

### 11. Other Investigations.

(*a*) *Investigation of Beef Production in Australia.*—

(i) *Survey of Beef Cattle Production.*—This survey has been continued (*see* Chapter VIII., Section 6 (*a*)).

(ii) *Quantitative Carcass Appraisal.*—A promising system has been developed (*see* Chapter VIII., Section 6 (*b*)).

(iii) *Studies on the Bovine Skin.*—These studies were commenced in September, 1949 (*see* Chapter VIII., Section 6 (*c*)).

(iv) *Beef-cattle Feeding Investigations.*—These investigations have been continued (*see* Chapter VIII., Section 6 (*d*)).

(*b*) *Survey of Fine Wool Production.*—Survey work is now in progress in Queensland (*see* Chapter VII., Section 19 (*b*)).

## VI. NUTRITION.

### 1. General.

The Organization's work on nutrition problems is largely confined to studies of the nutritional physiology of the sheep and the influence of nutrition on wool production. The work has been undertaken within the Division of Biochemistry and General Nutrition, which has its head-quarters and laboratories situated within the grounds of the University of Adelaide.

The remainder of this Chapter outlines the work of this Division, but further details of various investigations on sheep nutrition are given in Chapter VII., Sections 2, 3, 4, 8, 10, and 11, and details of the mineral deficiency studies carried out on the Ninety-mile Plain are to be found in Chapter III., Section 22. The new knowledge arising from much of this research is rapidly finding its way into practice, and it is especially gratifying to find application following so closely on the achievements of research.

*Division of Biochemistry and General Nutrition.*—The new laboratory building in the grounds of the University of Adelaide has now been completed, and has gone far toward relieving the previous congestion. Further improvements have been made to the Division's Central Field Station at Glenthorne, which is situated about 11 miles from the main laboratories, and active research is now proceeding there.

The spirit of research within the Division has continued to be healthy and vigorous. It is fostered by the close association with the University of Adelaide. Application of the results has been materially assisted by the close liaison which has grown up between the Division and the State Departments of Agriculture, and by association with other bodies whose duties and interests are to ensure the rapid and efficient application of research findings to the pastoral industry.

### 2. Nutrition and Wool Production.

Study of the relationship between nutrition and wool production has been continued and extended. This work is reported in Chapter VII., Section 2.

### 3. Metabolic Studies.

The first part of the investigation of the relative usefulness of the lower fatty acids as fuel to support the energy requirements of the sheep is now practically complete, and the results are being prepared for publication. These, together with the findings from the studies of the intermediary metabolism of the fatty acids, have provided for the first time a basis of secure knowledge of the energy metabolism of the sheep. The elucidation of the metabolic disorders met with in grazing sheep will, in consequence, be greatly facilitated.

This work, which is concerned with (*a*) the utilization of urea, (*b*) the fermentation of carbohydrates in the rumen, (*c*) the absorption of fatty acids from the rumen, (*d*) the intermediary metabolism of fatty acids, and (*e*) ketone production by the sheep, is described in Chapter VII., Section 3.

### 4. Vitamin A Requirements of the Sheep.

The series of studies on the vitamin A requirements of the sheep has been continued; they are described in detail in Chapter VII., Section 8.

### 5. Effects of Chronic Fluorosis in the Sheep.

These studies have been continued. An experiment to determine the effects on grazing sheep of the regular ingestion of small amounts of fluorine in the drinking water has been commenced. The results obtained so far are reported in Chapter VII., Section 10.

### 6. The Amino-Acid Constitution and Chemical Structure of Wool from Copper-Deficient Sheep.

The physico-chemical structure of the abnormally keratinized wool grown by copper-deficient sheep has been studied further, in an attempt to find the origin of the difference in acid-combining capacity between the wool from normal and from copper-deficient sheep. This work is as yet not completed. Already, however, the study of the copper-deficiency lesion has thrown considerable light on the structure of normal wool fibre.

### 7. Influence of Heavy Metals on Phosphorylation.

In some preliminary experiments an examination was made of the phosphorus metabolism of Algerian oat plants grown in water culture deficient in copper or zinc. While the plants remained vegetative, labile phosphate in the zinc-deficient plants was very low, whereas total phosphate was exceedingly high. When the zinc-deficient plants ran up to head during late October and November, total phosphate declined and labile phosphate increased. It is possible that a greater intake of zinc occurred at this time, despite the precautions that were taken to keep it out of the culture solutions, since in the warmer weather the transpiration from the leaves and evaporation from the pots increased the requirements of glass-distilled water very materially. It is also possible that the greater length of day enabled the zinc-deficient plants to minimize the effect of a bottleneck in metabolism due to low levels of zinc. This is being investigated further. Labile phosphate in the control plants declined as they reached maturity. The copper-deficient plants remained in the vegetative condition throughout, and the labile phosphate did not decline to the low levels of the controls. The total phosphate was high in this group. There was a reciprocal relationship between copper and zinc content. Copper levels rose above normal in the zinc-deficient plants, and zinc levels rose above normal in the copper-deficient plants. The phosphorus/zinc ratio averaged 250:1 in the copper-deficient and control plants, and 1,000:1 in the zinc-deficient plants. Further experiments are in progress.

As a part of a comprehensive study of the influence of molybdenum on copper metabolism, a preliminary examination was made of the effect of molybdate upon the oxidation of tyrosine by mushroom tyrosinase, and of ascorbate by copper ions. The uptake of oxygen by the system was used as a measure of the integrity of the catalyst. It was found that molybdate had little, if any, influence on the effectiveness of mushroom tyrosinase or upon copper ions *in vitro*.

### 8. Minor Elements in Animal Nutrition.

The study of the physiological function assumed by traces of heavy metals in the metabolism of animals, mentioned in the last Report, has been continued both in the laboratory and in the field. Details of the studies on cobalt deficiency, on copper deficiency, and on the influence of molybdenum on the metabolism of copper are given in Chapter VII., Section 11.

### 9. Plant Nutrition.

Further studies have been made of the mineral nutrition of plants in the Ninety-mile Plain, South Australia, and an ecological study of this area has been completed. This work is described in detail in Chapter III., Section 22.

### 10. Accessory Food Factors and Food Compositions.

It was found that pure vitamin $B_{12}$ completely counteracted the retardation of growth which occurred when thyroxin was administered to young rats fed on a diet consisting largely of soybean and ground maize. An acid precipitate prepared from the water extract of sheep faeces had an effect on growth similar to that of vitamin $B_{12}$. The corresponding precipitate from the faeces of cobalt-deficient sheep fed in the same manner had only about half the vitamin $B_{12}$ activity of the material from normal sheep. Either vitamin $B_{12}$ or the acid precipitate from sheep faeces restored to normal the efficiency of food utilization by rats receiving thyroxin.

Preliminary work was carried out on the development of a micro-biological method for estimating pantothenic acid.

### 11. Radioactive Isotopes.

The work on the estimation of $C^{14}$ has been continued and instruments have been assembled with which critical assays of small amounts of $C^{14}$ may be made with relative ease. A series of compounds in which certain of the carbon atoms are tagged with $C^{14}$ has been synthesized for use in metabolic studies.

### 12. Reactions of Amino-acids.

The observation by Fischer that sodium hydroxymethylene acetone and glycine in alkaline aqueous solution rapidly react yielding a product which gives a positive Ehrlich reaction (*p*-dimethylaminobenzaldehyde) has been confirmed. Interest was aroused in this reaction because of Fischer's opinion that the product formed was a pyrrole, and this, taken along with Rittenberg's work showing the incorporation of glycine nitrogen in the tetrapyrroles of the blood pigments, indicated a possible mechanism for biological pyrrole synthesis. It has been shown that the reaction is in no way specific for glycine, for of 21 α-amino acids tested, eighteen were found to give positive results. The influence of the pH of the reaction medium has been studied; it has been observed that the reaction does not proceed at pH 6, and at pH 6 to 7 the reaction is slow and incomplete for all acids except the dicarboxylic acids glutamic and aspartic acids, which do not react at all at this pH. All acids except *n*-acetylglycine, cysteine, and *p*-hydroxyphenylglycine react at pH 8. This suggests that the reaction involves the free α-amino group in an unionized condition, since more alkaline conditions are required for the reaction to proceed with amino acids having high isoelectric points. The fact that the reaction proceeds readily with the strongly basic glycine ethyl ester or β-phenyl-α-alanine, and the negative results obtained with *n*-acetylglycine, tend to confirm this. Among the α-amino acids tested was α-amino-isobutyric acid. This compound gave a positive reaction, and since the carbon atom holding the amino group is tertiary it is impossible for Fischer's proposed pyrrole synthesis to occur in this case. This, together with the observed rapid hydrolysis of the reaction product with dilute acid, has thrown considerable doubt on the validity of Fischer's proposal.

The substitution of acetylacetone for sodium hydroxymethylene acetone has not led to any clear-cut results. In the cold the reaction proceeds slowly if at all, but if the reactants are heated a positive reaction with Ehrlich's reagent is obtained. This result is complicated by the observation that acetylacetone heated with inorganic alkalis decomposes to a product which also gives a positive colour reaction. From β-phenyl-α-alanine and acetylacetone, for instance, it is possible to isolate a crystalline product, presumably formed by simple dehydration, which gives a negative Ehrlich reaction whilst the residues from the reaction mixture react positively.

From the reaction of sodium hydroxymethylene acetone with glycine, crude sodium salts giving strong positive colour reactions have been isolated, but their extreme solubility in water and methanol, insolubility in other solvents, extreme sensitivity to acid hydrolysis, and decomposition in ion-exchange columns have prevented purification and characterization. The more amenable copper salts are now being studied.

A copper salt has been isolated from the reaction product of β-phenyl-α-alanine and sodium hydroxymethylene acetone. Copper estimations on partially purified products give results corresponding to those required for a simple dehydration product, but purer samples may lead to revision of this view. Further analyses have been made.

Most satisfactory results have been achieved by studying the reaction of glycine ethyl ester hydrochloride and sodium hydroxymethylene acetone. The reaction proceeds rapidly in non-aqueous mediums and from the product a copper salt crystallizing readily from common solvents has been obtained. This is being examined.

### 13. Field Stations.

(*a*) *Glenthorne*.—The experiment on the relationships between molybdenum and copper in the sheep, mentioned in the last Report, was continued. The results are reported in Chapter VII., Section 11 (*b*).

An experiment to determine the effects on grazing sheep of drinking water containing 10 or 20 p.p.m. fluorine was commenced. This experiment, involving about 200 sheep, is described in Chapter VIII., Section 10.

Developmental work has been carried out during the year. A further 30 acres was sown to permanent pasture and the pasture sown in 1949 has now been established. On an additional 50 acres contour banks have been built for the conservation of soil and moisture. A concrete tank with a capacity of 50,000 gallons has been built and consequently the water supply for next summer is now assured. Pine trees were planted along portion of the western boundary in the winter of last year and a small nursery was established to produce trees for future planting.

The equipment for compressing foodstuffs into pellets suitable for experimental feeding is now almost complete; a power mixer and a hammer mill were installed during the year. The equipment is still, however, in temporary locations. The Station is now able to supply most of the foodstuffs required by the Division for experiments with sheep.

About 700 sheep and lambs were shorn. The adult sheep, including weaners and wet ewes, produced an average of 15 lb. of wool per head.

(*b*) *Other Field Stations.*—The field investigations of the effects of minor element deficiencies have been continued at the Division's field stations at Robe, Keith, Borrika, Glenroy, and Kybybolite. Much of this work has been mentioned above; details are given in Chapter VII., Section 11.

A field station to study the effects on grazing stock of pastures developed on the zinc- and copper-deficient terrain of the Ninety-mile Plain is in the course of being set up at Brecon, near Keith.

## VII. SHEEP.

### 1. General.

Work on the sheep has been undertaken by the Divisions of Animal Health and Production and of Biochemistry and General Nutrition (*see* Chapters V. and VI. respectively). Sections 2, 3 (*f*), 5-7, 9, and 12-19 of this Chapter relate to investigations carried out by the Division of Animal Health and Production, and Sections 2, 3 (*a*)-(*e*), 4, 8, 10, and 11 to those of the Division of Biochemistry and General Nutrition. Much of the Organization's work on soil infertility and pasture improvement (Chapters II. and III.) also is of obvious importance to the pastoral industry.

The work of the Organization's Wool Textile Research Laboratories is described in Chapter XV.

### 2. Nutrition and Wool Production.

In a further study of the nutritional factors which determine wool production, the Division of Biochemistry and General Nutrition has carried out critical balance experiments to investigate several outstanding problems of the inter-relationship between the efficiency of utilization of protein and the state of the energy balance. The results confirm our previous findings that there can be no doubt that the rate of wool growth depends on at least two factors, the state of the energy balance and the intake (and quality) of protein. Claims that the rate of wool growth is related exponentially to the intake of protein are certainly erroneous except in the special case when the energy intake remains constant.

Other aspects of the general problem of nutrition and wool production have received the constant attention of the Division of Animal Health and Production. The effects of seasonal variation on the available food supply and on the energy requirements of sheep, as well as the extra demands for food in late pregnancy and during lactation, in relation to health and wool production, have been studied. Studies have also been made of the effects of atmospheric temperature on the utilization of food and on the growth of wool. Experiments designed to determine the variation in wool-producing capacity of particular strains of sheep under standard nutritional conditions have been carried out.

### 3. Processes of Rumination.

(*a*) *Utilization of Urea.*—The experiment mentioned in the last Report was continued. Amounts of 50, 100, 150, or 200 g. potatoes per day were given to the various groups, and in addition a daily supplement of 28 g. mixed peanut and palm oils was given to the first two groups, 14 g. of the oil to the third group, and no supplement of oil to the fourth group. Half the sheep of each group received 15 g. urea daily, equivalent to approximately 7 g. nitrogen, for an experimental period of seven weeks. The treatment was then reversed for a similar period.

The increases in wool during the periods when urea was fed were 1, 9, 15, and 16 per cent., for the groups receiving 50, 100, 150, and 200 g. potatoes daily, respectively. The corresponding increases in fibre diameter were 2, 3, 3, and 6 per cent.

The results of the two portions of the experiment were submitted to statistical examination. When oil was added to the ration the supplement of urea caused a significant increase in wool production with 100 g. or more of potatoes daily. When oil was not added to the ration a significant increase due to urea occurred with 150 g. or more of potatoes, but the increase with 100 g. potatoes was hardly significant.

It would appear that under the conditions of the experiment an increase in wool production occurred as the result of the intake of urea when the ration contained at least 100 g. potatoes daily.

To test the effect of supplementary feeding with urea plus starch in the field, grazing sheep in an area where a severe and prolonged protein deficiency is an annual occurrence will be fed this mixture. The urea will be given in the form of a ration of nuts which will supply 100 g. wheat and 15 g. urea daily, and the effects which this has on wool production will be contrasted with a ration of wheat and casein supplying approximately the same amounts of nitrogen and available energy.

(*b*) *Fermentation of Carbohydrates in the Rumen.*—This work has been extended to include further fermentations of wheaten hay, and in addition the fermentation of a second type of fodder, lucerne hay, has been investigated. The results confirm and extend those reported last year. The experiments have been described in a paper submitted for publication.

Implications of the *in-vitro* work (above) respecting the relative rates of absorption of the individual fatty-acid products were put to the test by a close examination of changes in the composition of the rumen fluid throughout the day. Sheep were fed either lucerne hay or wheaten hay and samples of the rumen fluid were analysed at frequent intervals before and after feeding. During the increase and decrease in the concentration of fatty acid in the rumen which follows on feeding, certain characteristic changes occurred in the proportions of the individual acids present. These changes were in good agreement with predictions made from the findings of the *in-vitro* fermentations. The experiments have been described in a paper submitted for publication.

A study of the gases formed in *in-vitro* fermentations of wheaten hay and lucerne hay has been made. In the 48-hour fermentations 15-20 l. methane and 40-60 l. carbon dioxide per kg. of fodder were produced. The rate of production of methane was found to reach a maximum about eight hours after the fermentation was started. No hydrogen was formed. When fermentations were initiated by inocula drawn from fasting sheep, large amounts of hydrogen were formed.

An investigation of the production of methane from mixtures of carbon dioxide and hydrogen by micro-organisms from the rumen has been started. This work is an extension of experiments reported earlier from this laboratory.

The fraction of the rumen fatty acids usually designated "butyric acid" was separated from about 90 l. of rumen fluid and was found to have the following molar composition: *n*-butyric acid 70 per cent., isobutyric acid 5 per cent., valeric acid 20 per cent., acid or acids higher than valeric acid 5 per cent. The separation of butyric acid from valeric acid and higher acids was made on a partition-chromatographic column designed for the purpose.

An investigation has been begun to examine the nutritional significance for the sheep of the synthesis of polysaccharides by the bacteria and protozoa of the rumen; with this end in view, methods for sampling the rumen contents, separating the micro-organisms, and determining the starch-like polysaccharides in them, are being studied. When these are satisfactory, the amount of starch or glycogen-like polysaccharides available for digestion in the small intestine will be assessed.

(*c*) *Absorption of Fatty Acids from the Rumen.*—The work described above gave some indication that the relative rates of absorption of the fatty acids might differ according to the proportions in which the individual acids were present in the rumen. This has led to the initiation of further work. A study has been made of the changes in the composition of the rumen fluid after introducing pure fatty acids into the rumen at the end of the feeding cycle (i.e., in lieu of feeding at the beginning of the day). This work is as yet incomplete, but there is evidence which suggests that the permeabilities of the acids (permeability = amount absorbed in unit time/concentration in rumen) are dependent on their concentrations in the rumen. In other words, there appears to be evidence for active transfer rather than passive penetration of the acids through the rumen wall. The final interpretation of the data from such experiments must await the use of "tagged" acids, so that the possible effects of continued production of acids from food residues present in the rumen may be allowed for. It is intended to use acids labelled with $C^{14}$ for this purpose.

In continuation of the work described in the last Report, a number of analyses were made of the fatty acids present in arterial blood, jugular blood, and blood from the rumen vein. A very considerable part of the "volatile" acid distilled from blood in the procedure used by Barcroft and his colleagues was found not to be acetic, propionic, or butyric acid. This extra fraction moved more slowly than acetic acid on the chromatographic column and indications of the presence of at least three acids—formic, lactic, and succinic—were obtained. Nevertheless, the proportion of acetic acid to higher fatty acids in the blood of the rumen vein was undoubtedly greater than is usually found in rumen fluid, as was previously reported in confirmation of the findings of other workers. Until there is greater certainty of the validity of these methods for the determination of volatile fatty acids in blood, it is considered unsafe to draw definite conclusions from such analyses.

(*d*) *Intermediary Metabolism of Fatty Acids.*—In view of the relatively large amounts of acetate and propionate absorbed from the rumen, and of their importance in the metabolism of the sheep, experiments were conducted to elucidate some aspects of the metabolic routes followed by these substances. Solutions of acetic acid, propionic acid, and butyric acid neutralized with caustic soda were administered to sheep by intravenous injection, and the rate of removal of these substances from the blood was determined during the subsequent three hours. In order to assess any possible metabolic interrelationship which may exist between these lower fatty acids, equimolar mixtures of acetate and propionate or of butyrate and propionate were also administered to sheep. An indication of the intermediary metabolism of these lower fatty acids by the sheep was obtained by determining the level of ketone bodies, reducing sugar, lactic acid, and pyruvic acid in the blood subsequent to the injection of their sodium salts.

Analyses of the systemic blood indicated that acetate brought about no demonstrable rise in the sugar, lactic acid, or pyruvic acid in the blood; propionate, however, produced a marked elevation in their concentrations. The butyrate also led to an increase in sugar and lactic acid, and to a delayed but slight increase in pyruvic acid. This aspect is being investigated further. When acetate and propionate were administered together, the levels of sugar, lactic acid, and pyruvic acid rose, but the pyruvic acid increased to a less extent than when propionate only was administered. This study of the metabolism of the lower fatty acids and its relationship with the carbohydrate intermediaries is being continued.

(*e*) *Ketone Production by the Sheep.*—From observations made on the level of ketone bodies in the systemic circulation after the intravenous injection of either acetate, propionate, butyrate, or an equimolar mixture of acetate and propionate, the ketogenic nature of acetate and butyrate has been confirmed. Propionate, however, was observed to bring about a reduction in the level of circulating ketone bodies, and the presence of propionate in the equimolar mixture of acetate and propionate prevented the rise that would have followed the injection of the same amount of acetate unaccompanied by the propionate. This work is being extended in an attempt to determine the metabolism of acetate in conjunction with the concurrent supply and metabolism of propionate. It is an aspect that is of some importance in relation to the general production and metabolism of ketone bodies in the sheep under various nutritional conditions.

(*f*) *Effect of Diet on Production of Lactic Acid and Ammonia in the Rumen.*—At the McMaster Animal Health Laboratory sheep have been fed on rations which differ widely in the content of fibre, starch, and protein. The studies have been carried out to determine the conditions under which lactic acid and ammonia accumulate in the rumen.

### 4. Energy Metabolism.

Work is continuing in this field but no new developments are reported.

### 5. Carbohydrate Metabolism.

Experiments with insulin have indicated that the hormonal control of carbohydrate metabolism in ruminants probably differs from that in monogastric animals, and that the tissues of the sheep dispose of glucose very slowly compared with monogastric animals. The dominant rôle in the energy metabolism of sheep is played by acetic acid, which accounts for about 90 per cent. of the total volatile fatty acid in arterial blood. It has been shown that the volatile fatty acid which is removed from the sheep's blood by its tissues is acetic acid, which appears to serve the ruminant very largely in place of glucose. Glucose in the sheep is derived through the conversion of propionic acid in the liver. This occurs so rapidly that propionic acid absorbed from the rumen rarely reaches the general circulation as such. Indications have also been obtained that formation of glucose in the liver from protein or fat during fasting does not occur as readily in sheep as in monogastric animals. A technique has been devised for separating and identifying volatile fatty acids by paper chromatography.

### 6. DROUGHT-FEEDING EXPERIMENTS.

These investigations are being conducted at Glenfield in collaboration with the New South Wales Department of Agriculture. The costs so far have been met by a grant from the Burdekin Bequest, administered by the Graziers' Association of New South Wales. The first series of trials commenced in November, 1948, and terminated in February, 1950, and the results are being prepared for publication. These trials were designed to compare the results of daily and weekly feeding at drought-ration levels and to determine the minimal requirements of roughage in drought rations. Four different mixtures (by weight) of wheaten chaff and wheat were used, namely 50:50, 30:60, 20:80, and 10:90. All rations included 1.0 per cent. of finely ground limestone. Adult wethers were used for this work, to ensure that the experimental animals were as stable as possible.

The sheep fed once a week on these rations thrived as well as those fed daily and their survival rate was much higher. Greasy-wool and scoured-wool production was slightly greater with groups fed weekly and, under the conditions of the experiment, the cost per head (purchase of feed and losses by death) of bringing sheep through a complete drought of almost 12 months' duration was considerably lower when the sheep were fed weekly than when fed daily. The best results were obtained with groups fed weekly on the diet of ten parts chaff and 90 parts wheat, and the worst results were obtained in groups fed daily on this mixture. The sheep originally weighed about 90 lb. per head; they were reduced over a period of several weeks to about 75 lb. per head, and were then gradually brought on to the experimental rations at a level calculated to maintain them at that weight. The strikingly better results from weekly feeding can be explained by the fact that the quantity of feed supplied daily to sheep on drought rations is small and can be consumed quickly. Hence the stronger sheep consume most of the group's ration and the weaker or slower feeders go hungry. Groups fed weekly took about four days to consume the week's ration, so that even the weakest sheep could get its share.

Another series of experiments was commenced to compare grain sorghum with wheat as a concentrate for use in drought rations, to study the results of feeding at considerably lower levels than were used in the preceding series, and to note the effect of walking measured distances on the body weight and general behaviour of sheep on drought rations. The rations used in the first series of experiments provided the sheep with over four food units (starch equivalents) a week, whereas the rations frequently recommended for use in times of "complete drought" provide less than three units a week.

### 7. TOXICITY OF LARGE RATIONS OF WHEAT.

In the last Report it was suggested that the large amounts of wheat found necessary to produce fatal illness in sheep on a high plane of nutrition might not be necessary to produce the same result in animals on a low plane of nutrition. This has since been found to be so: when the mean body weight was reduced from 74 lb. to 55 lb. over a period of a month by restricted intake of a poor diet, the lethal dose of wheat administered approached 50 g./kg. instead of the previous figure of 75-80 g./kg. However, none of a group of 24 such sheep would voluntarily eat lethal amounts of wheat.

Success has followed a modification of the procedure. After a month on a reducing diet the sheep were gradually accustomed to wheat by adding it in increasing proportions to their restricted ration so that at the end of twelve days they were consuming 80 per cent. crushed wheat.

During this preliminary reducing and accustoming period the mean body weight fell from 96 to 70 lb. (27 per cent.). After a fasting period of one day they were given crushed wheat *ad libitum*. Under these conditions, it is impossible to know how much wheat individual sheep consumed, but nine out of 25 animals died in the ensuing two days although the mean consumption of wheat was only 2.5 lb.; to this might be added the cumulative effect of undigested wheat consumed during the twelve-day accustoming period (total mean intake 4.6 lb.). Several animals developed lameness to various degrees. A number of the rapidly fatal cases were examined in some detail and similar findings to those observed in sheep dying after administration of wheat were observed, namely, very low ruminal pH, low blood pH, and rise in blood lactate to 100-150 mg./100 ml. Some others, including those which showed only lameness, developed low ruminal pH values, but blood lactate did not rise higher than 60 mg./100 ml., and the blood pH did not fall to low levels. The examination of material is not complete, but it is evident that in the field at least some of the deaths are associated with a similar train of events to those observed when wheat is forcibly administered, namely, abnormal ruminal fermentation with lactacidaemia and acidosis.

Five control sheep were allowed unlimited amounts of the poor diet during a month and of the diets containing increasing proportions of wheat during the twelve-day accustoming period. They virtually maintained their weight, which fell from 92 lb. (mean) to only 89 lb. During the accustoming period the total mean consumption of wheat was about 20 lb. per head. After a fasting period of 24 hours they were offered unlimited wheat but ate only about 1 lb. per head and none developed lameness or illness.

These experiences make it evident that a low plane of nutrition and hunger are important factors in the occurrence of fatalities in sheep which have become used to eating wheat.

Further confirmation was obtained that low pH (4.2) favours absorption of lactic acid from the rumen. It was also found that whereas acetate and propionate are cleared quickly from the blood stream after intravenous injection, clearance of equimolar amounts of *dl*-lactate takes at least six times as long. These factors, together with the high concentrations reached (up to 1.3 per cent. or 0.14 M) help to explain why lactate accumulates in the blood after heavy rations of wheat and why acidosis follows.

The suggestion that another factor might be the preponderance of the laevorotatory isomer has not been examined directly, but subsequent observation has shown that in fatal cases the ratio of laevorotatory to dextrorotatory lactate in the rumen has varied considerably from 6:1 to 1:2, probably depending upon the lactobacilli or streptococci present and on bacterial associations.

### 8. VITAMIN A REQUIREMENTS.

The experiment mentioned in the last Report was continued. Although the diet supplied less than 10 $\gamma$ carotene per kg. body weight per day, the concentration of vitamin A in the blood decreased very slowly. By the end of sixteen months it had fallen from an initial mean of 34 $\gamma$ to 20 $\gamma$/100 ml. plasma. Eighteen ewes were then divided at random into three groups which were offered, respectively, sufficient lucerne meal to bring the intake of carotene to 50, 75 or 100 $\gamma$/kg. body weight per day. Four ewes, in which the concentration of vitamin A in the blood had remained constant at approximately 30 $\gamma$/100 ml. plasma for ten months, were kept on the low-carotene basal ration. All were mated. The concentration of vitamin A in the blood of the control group declined steadily during the next six months to 17 $\gamma$/100 ml. plasma; it remained almost constant (23 $\gamma$/100 ml.) in the group receiving 50 $\gamma$ carotene/kg. body weight; and rose to 29 and 31 $\gamma$/100 ml. in the groups receiving 75 and 100 $\gamma$ carotene/kg. respectively. Lambing appeared to be satisfactory in all groups, including the control group. This does not necessarily indicate that reproduction can be normal at the levels of intake which were used, but more probably that the ewes still had sufficient reserves of vitamin A to enable them to complete a gestation period successfully. Lactation for a period of up to four weeks caused a further decline in blood vitamin A levels. It is proposed to retain the ewes for a further period on the basal ration, until the blood levels are between 10 and 15 $\gamma$/100 ml. plasma and then to mate and supplement with carotene as before.

### 9. VITAMIN D SUPPLEMENTS.

Further experiments were carried out in Tasmania at Frodsley and at the Cressy Experiment Farm during the winter of 1949, with the co-operation of the Tasmanian Department of Agriculture. In these trials, weaners grazing green oats with subterranean clover and rye grass showed increased gains in body weight and produced more wool when provided with additional vitamin D. The vitamin D was given as " Calciferol ", either as a single dose early in the winter, or as two doses in early winter and mid-winter. The doses ranged from 500,000 to 1,000,000 international units of vitamin D for each sheep. There was a negligible response to vitamin D supplements by weaners wintered on ordinary pastures on these properties during the same period. The requirements of vitamin D by weaners during the winter months, in latitudes where the intensity of ultraviolet light is low, is associated with the rate of growth engendered by the feed available. If the feed is insufficient to support growth the requirement of vitamin D is reduced accordingly and supplements are of no advantage.

In the trial at Frodsley, for example, pasture-fed weaners, even though receiving a generous allowance of hay, grain, and chaff in addition, barely maintained weight and showed no benefit from vitamin D supplements. Similar weaners on good green feed throughout the 20-week period increased by some 2 lb. live weight per week and produced over 50 per cent. more wool than those on pasture. These were the sheep which benefited by administration of vitamin D.

### 10. CHRONIC FLUOROSIS.

The previous experiment showed that the ingestion of water containing as much as 10 or 20 p.p.m. fluorine did not adversely affect the growth or wool production of sheep kept in pens for three and a half years on a ration of chaff and grain, although the treatment did induce some degree of mottling of the incisors and molars, and selective abrasion of the latter. Two experiments were then begun at Glenthorne with grazing sheep receiving water containing 10 or 20 p.p.m. fluorine.

In one experiment three groups of 50 ewes were placed, each with a ram, in adjoining paddocks during November, and subsequently the groups were rotated between the paddocks. One group was given reservoir water containing approximately 0.3 p.p.m. fluorine to drink. The other two groups received the same water to which sufficient sodium fluoride had been added to bring the concentration to 10 and 20 p.p.m. fluorine respectively. Shortly after lambing most of the ewe lambs and their mothers were removed from the experiment, but the ram lambs and their mothers, eighteen in each group, were retained. Ten ewe lambs were retained in each of the control and 20-p.p.m. groups. The lambs will be weaned at about five months of age and continued in the experiment until the eruption of their permanent teeth is completed. The ewe lambs will be mated at two and a half years of age. They will be weighed weekly and their incisor teeth will be examined periodically.

Lambing was satisfactory in all groups, the percentage of ewes lambing in the control, 10-p.p.m. group, and 20-p.p.m. group being 93, 98, and 98 respectively, and the corresponding percentages of lambs being 105, 121, 119. This indicated that the drinking of water containing 10 or 20 p.p.m. fluorine over the entire period of gestation had not adversely affected reproduction.

In the second experiment three groups each of eighteen wethers, aged two and a half and three and a half years, were placed in the same three paddocks as the ewes and offered the same water supplies, the two experiments being started simultaneously. The wethers are weighed at fortnightly intervals and their incisor teeth are inspected periodically. After seven months of the experimental treatment no difference has been detected between the three groups.

### 11. MINOR ELEMENTS IN ANIMAL NUTRITION.

(*a*) *Cobalt Deficiency*.—(i) *The Physiological Function of Cobalt*.—Previous reports have pointed out that cobalt introduced into the blood stream is without therapeutic effect, but that cobalt directed to the abomasum in sheep drenched *per os* seemed to be as effective as cobalt introduced into the rumen. In sheep with fistulae in both rumen and abomasum, no evidence of regurgitation of material from the abomasum to the rumen could be detected. The findings from preliminary experiments suggest that cobalt administered directly into the abomasum *via* a fistula may prevent symptoms of deficiency from developing in sheep confined for eight months to deficient pastures. These observations are being extended by direct injection of cobalt into the abomasum of cobalt-deficient sheep that are fed in pens on cobalt-deficient rations.

(ii) *The Anaemia of Cobalt Deficiency in Sheep*.—The response of the anaemia of cobalt deficiency to massive doses of concentrated liver extract, administered *per os* and by intramuscular injection, is being compared at Robe.

(iii) *The Quantity of Cobalt Necessary for Complete Nutrition of the Sheep*.—During the third year of treatment it has become apparent that a supplement equivalent to 0.05 mg. cobalt per day no longer maintains sheep completely. The ewes of this experiment have been mated and the responses of their lambs to the levels of supplementation referred to in previous reports will be studied.

(iv) *The Practical Control of Cobalt Deficiency*.—Single applications of cobalt sulphate to deficient pastures at the rate of 1 lb./acre have proved not to overcome effectively the cobalt deficiency (*vide* Robe and Glenroy). The efficacy of massive, infrequent doses of cobalt in correcting deficiency is being examined at Robe.

(*b*) *Copper Deficiency in Sheep and the Influence of Molybdenum on the Metabolism of Copper*.—The extensive use of the liver aspiration biopsy technique has greatly facilitated the study of copper metabolism. Studies relating to the storage of copper in the liver of sheep supplemented with copper under a variety of conditions have been continued and extended. Several of these studies are of immediate significance in the practical control of copper deficiency in the field.

(i) *Intravenous Injection of Copper Sulphate Solutions*.—From 50 to 100 per cent. of single injections (15-45 mg. Cu), or of injections administered on successive days, has been found stored in the liver 24 hours after the injections. This finding applied equally in normal and in copper-deficient sheep.

(ii) *Oral Drenching of Copper Salts.*—Less than 10 per cent. of single doses of copper sulphate or of copper chloride (100, 250, and 500 mg. Cu) was found to be stored in the liver three days after drenching; usually the amount stored was less than 3 per cent.

(iii) *Copper Sulphate Solutions Injected into the Abomasum.*—Injection of 250 or 500 mg. Cu directly into the abomasum produced a rapid, catastrophic rise in blood copper in mature sheep, which died within 24 hours. These observations stress the dangers inherent in the use of massive doses of copper when administered in this way. This work is being extended.

(iv) *Control of Copper Deficiency by Infrequent, Massive Doses of Copper Sulphate.*—On deficient pastures at Robe the extent of copper storage in the livers of ewes that are being dosed with 140 mg. Cu once in two weeks, and 280 or 560 mg. Cu once in four weeks, is being measured. Similar observations will be made with sheep consuming fodder which contains an adequate concentration of copper.

(v) *The Influence of Chronic Ingestion of Molybdenum on the Utilization of Copper by Sheep.*—The influence of chronic ingestion of an excess of molybdenum on copper storage in the liver has been determined at Robe. Assays of liver samples taken by biopsy after 100 weeks indicate that molybdenum favours copper retention and prevents the excessive accumulation of iron in the tissues. But this retained copper is obviously not available for all metabolic processes, as the animals suffered definite symptoms of deficiency long before the controls which did not receive additional molybdenum. The ewes have been mated in order to determine the incidence, if any, of nervous sequelae in their lambs.

(vi) *The Influence of Chronic Ingestion of Molybdenum on the Concentration of Copper in the Livers of Grazing Sheep.*—The concentration of copper in the livers of the groups treated with molybdenum (5 to 50 mg. molybdenum per day) is still below that of the controls, irrespective of the amount of molybdenum ingested. After 20 months the copper status of no animal in the treated groups has been depleted sufficiently to impair normal physiological functions. The experiment is being continued.

(vii) *The Influence of Chronic Ingestion of Molybdenum on the Copper Status of the Rat.*—Studies on the production of copper deficiency in the rat were continued and the findings mentioned in previous reports were confirmed. With increasing intakes of copper it was found that growth rate, storage of copper, and pigmentation reached an asymptote at a level of about 8 $\gamma$ Cu per day. Animals receiving the non-sulphided diet, supplying about 7 $\gamma$ Cu/day at four weeks of age and increasing to between 16 and 20 $\gamma$/day at 13 weeks, were shown to be in a state of incipient deficiency; pronounced improvement of copper storage and marked increase in pigmentation occurred when the diet was supplemented with 3 $\gamma$ Cu/day. When the non-sulphided diet was supplemented with 1,000 $\gamma$ Mo/day, the only appreciable effect was to increase the blood copper from 0.24 mg./l. to 0.42. Slight increases in the copper content of kidneys, spleen, and heart also occurred. These findings are in contrast with the large increases in copper storage at this level of molybdenum intake when the copper was fed solely as a supplement. Tungsten fed at the rate of 1,000 $\gamma$/day appeared to have no effect on growth or copper storage in the adult rat.

(viii) *The Influence of Copper Deficiency on Storage of Iron.*—It has been shown that the great increase in iron concentration in the livers of sheep subjected to acute copper deficiency for long periods may be dissipated when the copper status of the animals is restored to normal. This loss of iron contradicts the usually accepted view that stored iron is not lost from the body except by haemorrhage.

(*c*) *Field Experiments.*—(i) *Robe.*—Many of the experiments already described were carried out at the Field Station at Robe, South Australia. The following experiments were also conducted there.

(1) *The effect of dressing copper-deficient pastures with copper sulphate.*—The copper status of sheep grazing pastures treated with 14 lb. copper sulphate in 1940 is to be determined by liver biopsy. These animals continue to produce normal lambs although their wool at times shows some evidence of the copper-deficient lesion.

(2) *The effect of dressing cobalt-deficient pastures with cobalt sulphate.*—One lb./acre applied in 1944 has failed to provide sufficient cobalt to maintain normal health in sheep, although the treatment has delayed the onset of symptoms of deficiency.

(3) *Copper deficiency and wool growth.*—Sheep which normally grow black wool lost both the ability to elaborate pigment and to impart crimp to the fibres, when reduced to an acutely deficient status. Supplementary copper equivalent to 5 mg.Cu/day has restored crimp completely but has not restored pigmentation. The level of copper supplementation has been increased to 7.5 mg.Cu/day in an endeavour to simulate the conditions which induce " banding " in black wool in incipiently deficient regions.

(4) *Copper deficiency in English breeds of sheep.*—The effect of acute copper deficiency on the crimp of wool grown by pure Border Leicester, Lincoln, Romney Marsh, and Dorset Horn sheep is being studied.

(ii) *Keith.*—The lasting effect of a single application of copper sulphate at the rate of 7 lb./acre has been made clear by the copper concentration in liver samples taken at biopsy from sheep confined to such pastures during the fourth to seventh year after the dressing had been applied. Observations at this site will henceforth be confined to the examination each year of liver samples from sheep grazing these pastures.

(iii) *Borrika.*—As at Keith, a single application of 7 lb. copper sulphate per acre in 1943 enabled sheep confined to treated pastures to grow normal wool in 1949. Sheep grazing untreated pastures grew steely wool during the same period. Liver biopsy samples from the experimental groups will be examined during the next two years.

(iv) *Glenroy.*—Serious cobalt deficiency was encountered in 1949 in untreated experimental lambs for the first time since 1944. Lambs confined to an area which was dressed with 1 lb. cobalt sulphate in 1946 also showed definite, though less marked symptoms of cobalt deficiency. The length of time during which this amount of cobalt sulphate would correct cobalt deficiency completely was evidently less than four years.

(v) *Kybybolite.*—No response to cobalt or to copper supplements has been observed in the experimental flocks on this area.

### 12. Physiology of Reproduction.

(*a*) *The Influence of Nutrition on the Breeding Performance of Merino Ewes.*—Two groups, each of 50 Merino ewes, have been hand-fed on cereal rations, with and without a calcium supplement, since November, 1948. Each group is maintained in a half-acre yard. The groups were mated during February-March in 1949 and again in 1950. Data have been collected on conception and lambing rates, growth of lambs, appetite and lactation in the ewes, and the occurrence of hypocalcaemia in the ewes. There was no difference between these groups in conception and lambing rates from the first pregnancy, but a number of cases of hypocalcaemia occurred in the unsupplemented group. Lambs from the supplemented group were 50 per cent. heavier at weaning than those from the unsupplemented group. This was associated with the volume and duration of lactation; about one-third of the ewes in the unsupplemented group were still lactating at four months, as compared with 95 per cent. of those in the supplemented group. These experiments are being conducted at Glenfield, in collaboration with the New South Wales Department of Agriculture, and are financed by a grant from the Burdekin Bequest.

(*b*) *Cyclical Activity in the Reproductive Tract of the Non-pregnant Ewe.*—Work was confined to extending and confirming observations already made and to collating the data in hand.

(*c*) *Development of Reproductive Activity in Young Ewes.*—Observations on the three groups of ewes which were dropped at four-monthly intervals throughout 1947 and 1948 have been continued. Entire rams were run with the ewes continuously. Seven of the 64 ewes, five of them born during the 1948 sexual season, failed to bear lambs during the 1949 sexual season. One failed to exhibit oestrus. The lambing during 1949 spread from April to November. The observations are being continued to determine if and at what age pregnancy will ensue in the ewes which have failed to bear lambs, and whether a more concentrated lambing will occur as the ewes become older.

(*d*) *Development of Reproductive Activity in Young Rams.*—Seven of eight animals which grew quickly exhibited sperm in the epididymal smear when they were castrated between 125 and 154 days. Three of four animals which grew slowly failed to exhibit any sperm in the smear when they were castrated at 168-170 days. Correspondingly at comparable ages, testis and epididymus weights were lower and there was less separation of the prepuce from the penis in the slower-growing animals than in the fast-growing ones.

In the course of development of sexual behaviour, ram lambs were observed to pass through the following phases: (i) no interest was shown in ewes when they were placed with them, (ii) they moved around sniffing the perineal region of the ewes but showed no other reaction, (iii) in addition to sniffing, some preparation was made to mount, but mounting was not completed, and (iv) full copulatory activity was exhibited. Up to this stage it was clear that young rams were able to select ewes in oestrus only by the reaction of the ewes to copulatory advances. The advance to a ewe in oestrus was in no way different from that to one not in oestrus. The result was different only in that a ewe not in oestrus would move away when an advance was made whereas the ewe in oestrus would stand.

(*e*) *Early Prenatal Mortality in Ewes Induced by Hexoestrol.*—Hexoestrol has been used to terminate pregnancy in merino ewes in a preliminary approach to the study of prenatal mortality in these animals. As little as 0.5 mg. of hexoestrol given intramuscularly in oil has terminated pregnancy 28 days after mating, and doses of 2.0 mg. of freshly prepared solution consistently did so. Macroscopic evidence suggests that the termination of pregnancy is usually associated with some breakdown between the foetal and maternal placenta, following which the blood vessels in the foetal membranes disappear and resorption of the foetal fluids and degeneration of the foetus occur. On one occasion abortion of the products of conception was observed shortly after the administration of the hexoestrol.

Although pregnancy was terminated on a few occasions by the administration of hexoestrol 56 days after mating, this happened only irregularly and when doses greater than 100 mg. were given. A dose of 400 mg. failed to disturb pregnancy in one of two instances, as far as could be observed fourteen days later. The observations are proceeding.

(*f*) *Bio-assay of the Oestrogenic Activity of Subterranean Clover.*—The weight of the uterus in sprayed virgin female guinea-pigs has been found to be related to the dose of clover consumed when subterranean clover is consumed over a period of eight hours on each of two days, and the animals are slaughtered 50 hours after the start of feeding. The characteristics of the dose-uterine weight relationship have been defined and it has been shown that the relationship forms a satisfactory basis for the assay of relative activities of different samples of clover.

Assays have been made on this basis of the relative activities of clover samples taken at different times of the year, following different grazing treatments and, in co-operation with the Division of Plant Industry, following different fertilizer treatments. These tests have confirmed previous indications that the activity is at a peak during July and August and diminishes later in the season, have indicated strongly that grazed clover has a higher activity than ungrazed, and have demonstrated clearly that clover fertilized with superphosphate has a lower activity than unfertilized clover. Other tests have shown that appreciable activity may be lost when clover is dehydrated, but that dehydrated clover may be stored for periods of one to two years without further demonstrable loss of activity.

(*g*) *Infertility in Guinea-pigs Fed on Subterranean Clover.*—Pairs of guinea-pigs which had previously exhibited normal fertility did not produce any litters over a period of six to eight months during which the clover constituted one-third of their daily ration. Similar behaviour was exhibited by other pairs, to the females of which 500-100 γ of hexoestrol was fed daily. Litters were produced by some of the pairs after these treatments had been discontinued but fertility appeared to be of a lower order.

## 13. BREEDING AND GENETICAL STUDIES.

(*a*) *Inbred Flocks of Australian Merinos.*—The McMaster Field Station has continued the study of five inbred flocks of Merinos. The progeny of the five flocks have continued to show a downward trend in vigour, size, and fertility. Statistical examination of data relating to fleece characters of the flocks has shown no approach to uniformity among members of the several families and no further distinction of individual characters between families.

(*b*) *Investigation of Heterosis.*—Rams from the inbred flocks have been used to determine if their progeny from correlated Merino ewes, selected at random, might show hybrid vigour. This top-crossing experiment was carried out at the National Field Station, "Gilruth Plains". Analysis of birth weights of lambs from the matings gives no indication of heterosis among progeny groups of rams with levels of inbreeding, as indicated by Wright's coefficients, from zero to 25 per cent. Furthermore, there is no suggestion of any strain association. The possibility of decrease in the variability of fleece characters within the progeny groups, and its association with the levels of inbreeding of the sires, will be studied when the progeny reach a suitable age.

(*c*) *Polledness in Sheep.*—The investigation of polledness in sheep which was continued for several years has been brought to an end. A tentative hypothesis of the genetical basis has been advanced. From these studies it has become possible to define some of the requirements in breeding methods for establishing "polled" strains of sheep. Firstly, it is ssential to search for and use as parents only sheep with depressions at the horn site. Secondly, sheep with knobs at the horn site must be regarded as horned types having a low degree of hornedness. If due regard is given to these points when selecting parents, a flock with a low degree of hornedness can be evolved. Further, it is probable that horned strains of Southdowns or Border Leicesters could be evolved if desired, as the genes for hornedness are sufficiently frequent to make this possible. In some instances the preliminary selection could disclose relatively high degrees of hornedness. A Southdown ram from registered parents has been observed to have six-inch horns.

It appears, theoretically and from the results of experiment, that progeny testing of "depression" Merino rams would be time-consuming and unproductive. The multifactor situation which, it is suggested, controls the two characters, presents so many possible heterozygous combinations that the probability of discovering the very occasional homozygous animal is low. On the other hand, because "polledness" appears to be epistatic (or dominant) to "hornedness", mass selection for low degrees of hornedness is the most logical breeding method to employ. Theoretically, the method should give rise to dehorned sheep within a few generations, but it is unlikely to result in a flock which has maximal depressions uniformly. These were the results obtained with the breeding methods employed.

(*d*) *Inheritance of Component Fleece Characteristics.*—These studies have continued. The first lambs are about nine months old and the second mating of their parents was made.

(*e*) *Inheritance of "Hairiness" and "Fluffy-tip".*—The studies have been continued. An $F_2$ population is being built up to provide further data for analysis.

(*f*) *Study of Breeding Systems.*—The objects and methods of this long-term investigation, which is being carried out at the National Field Station, have been outlined previously. For the 1949 mating several of the families were recast. The Progeny Test Group moved into its second place with the mass mating of the sons of proven sires. Several of the selected families were abandoned. The mating for 1950 was reorganized. The grouping is as follows:—Group A—Mass Selection (phenotypic). Group B—Progeny Test Group; four sons, each being a son of the four proven sires in the original progeny test, are now being used. Group C—Family Group; six families are being studied; selection for particular character is practised; inbreeding is not controlled. Group D—Control Group; no selection in any form is practised; replacements at random from within the group.

(*g*) *The Study of Strains of Merino Sheep in Several Environments.*—The several strains selected for this study are placed at the National Field Station and at "Chiswick", Armidale, New South Wales. The plan includes a third centre which has not yet been established, but the site will be the Riverina, New South Wales.

The experiment has not yet continued long enough to yield information of any real significance. At Armidale heavy and continuous rain placed a strain on the sheep and on their management. A point of interest was the incidence of wool faults under these conditions. These faults consisted of "fleece rot", "yolk stain", bacterial discolouration, and cotting noted at shearing. Less than 1 per cent. of the fine-wool fleeces but 43 per cent. of the strong-wool fleeces were affected by these faults.

## 14. BIOLOGICAL STUDIES OF THE SKIN AND WOOL GROWTH.

(*a*) *Comparative Breed Studies.—An Experimental Study of Lincoln, Corriedale, Polwarth, and Fine-wool Merino Ewes on Standard Ration.*—The first stage of the experiment was completed. Four ewes of each breed were kept in individual pens for 44 weeks, from the age of about ten months to about 21 months. A standard high-quality ration providing 20 per cent. of crude protein was available in unrestricted quantity. The second stage of the experiment was started when all the animals were transferred to an arbitrarily chosen low plane of nutrition in four successive reductions of the dietary intake. The ultimate low-level intake will be one-fifth of the self-imposed high level.

Some of the results of the comparison of the breeds in the first stage of the experiment are summarized as follows:—

| Measurement. | Lincoln. | Corriedale. | Polwarth. | Fine Merino. |
|---|---|---|---|---|
| Food intake .. .. | 100 | 94 | 75 | 71 |
| Total clean wool .. .. | 100 | 88 | 64 | 57 |
| Fibre diameter .. .. | 100 | 81 | 65 | 47 |
| Follicle population density .. | 100 | 209 | 320 | 470 |
| Clean wool output g./g. nitrogen intake .. .. | 100 | 94 | 88 | 81 |
| Approximate value of fleece per unit food intake .. | 100 | 194 | 272 | 323 |

The figures show the relative values established under the particular experimental conditions. It was observed that when no interfering circumstances occurred all animals of all breeds attained maximal thickness of wool fibre in the fleece within four weeks of commencing unrestricted feeding, and thereafter maintained the values within narrow limits almost to the end of the 44 weeks of observation. It would appear that with the high quality ration used, most animals consumed at a rate of 25 per cent. in excess of what was necessary to maintain maximal uniform fibre growth. Only when food intakes fell below about 75 per cent. of the maximum achieved did fibre thickness become affected appreciably. The fine-wool Merinos maintained a maximal fibre thickness which did not exceed 21 $\mu$ at any time in any animal and averaged 19 to 20 $\mu$ throughout. In the sample of the breeds selected for the experiment, fibre diameter and follicle population density occupy intermediate positions.

(*b*) *Comparative Studies of Breeds of Sheep: Field Studies of Skin and Fleece.*—In these studies material was collected from Merino, Polwarth, Corriedale, Southdown, Dorset Horn, Ryeland, Romney Marsh, Border Leicester, and Lincoln breeds. A special study of follicle group size was made. The Merino stands entirely apart from all the other breeds of sheep in possessing the largest follicle group. It stands at one extreme of a potentially continuous series of follicle group size. Between the Merino and the British breeds there are no intermediate values except those provided by the hybrids. This probably suggests that the Merino as a distinct genotype possibly arose originally as a mutant. Both the short-wool and the long-wool groups differ very little from each other in follicle group size. They do show, however, a considerable and significant difference from each other in the relative thickness of the primary and secondary fibres.

(*c*) *Comparative Studies of Breeds of Sheep: Chemical Study of the Fleece of Merino and Corriedale Sheep under Experimental Conditions.*—Twenty-four whole fleeces, twelve Camden Park Merino and twelve Corriedale, have been sampled and considerable quantities of ether-soluble ("wax") and water-soluble ("suint") extracts obtained from 600-g. aliquots from the base, middle, and tip zones of the raw fleece. Important relative and absolute differences between the two breeds and also between individual sheep have been found in the character and the amount of the skin secretions.

The Merinos on a uniform intermediate plane of nutrition produced on the average 723 g. of "wax" and 246 g. of "suint". Corriedales under the same conditions produced on the average 610 g. of "wax" and 478 g. of "suint". The Merinos contained on the average 26 per cent. total cholesterol in the "wax" fraction and the Corriedales 39 per cent. The average total cholesterol values were 188 g. per head for the Merinos and 238 g. per head for the Corriedales.

## 15. SHEEP DISEASES.

(*a*) *Caseous Lymphadenitis of Sheep.*—The experiments on the protective value of annual vaccination one month before sheep are shorn, and of placing sheep directly "off shears" into a clean rested paddock, have been continued. None of the annual batches of sheep has yet come to slaughter and therefore the value of the methods cannot yet be measured. The first batch should be available for examination within the next twelve months and thereafter the three remaining batches will become available annually. New batches have not been added since July, 1949.

(*b*) *Toxaemic Jaundice of Sheep.*—The investigations have been continued by the Division of Animal Health and Production in active co-operation with the Veterinary Research Station, Glenfield, New South Wales, and with the assistance of other Divisions of the Organization. The two diseases under investigation are chronic copper poisoning of sheep and heliotrope poisoning of sheep. Neither of these diseases has been seen in other domesticated animals. The investigations on heliotrope poisoning, due to the consumption of *Heliotropium europaeum,* have been centred mainly at the field station at Barooga, New South Wales. The main experiment being conducted there is designed to determine the relative susceptibility of several breeds of sheep, Merinos, first cross Dorset Horn x Merino and first cross Border Leicester x Merino. The sheep graze the natural pasture in which the summer-growing annual plant, heliotrope, appears if the summer rainfall is adequate. The experiment will have to continue for a period of at least three years before results can be obtained. Other experimental groups of sheep have been grazed on a pure stand of heliotrope on an adjoining property where the germination and early growth of the plant were encouraged by the use of irrigation water. The sheep were given a second exposure to heliotrope in order to provide material for a closer study of the pathological processes excited by consumption of the plant. The results of the experiments have confirmed earlier observations that sheep must usually graze heliotrope in two consecutive seasons before the progressive liver damage leads to a high death rate in the flock. There is also strong evidence to show that if the diet of the sheep is of low nutritive value the damage to the liver becomes more severe and the death rate heavier. In a previous experiment it was found that a supplement of molybdenum increased the death rate. The experiment was repeated but similar results have not been obtained so far. Further progress was made in the isolation and identification of the alkaloids from *H. europaeum* by officers of the Division of Industrial Chemistry and toxicological studies on the pure substances were started.

The experimental study of chronic copper poisoning of sheep grazing on subterranean clover pasture has progressed. The pastures were established under irrigation at the field station at Cobram, Victoria. The experiment is designed to determine if an increased acidity of the particular soil type, Cobram sandy loam, favours the production of the disease. Considerable work was carried out in developing the property and the pastures, but results will not be available until about another two and a half years have passed.

Further studies, in pen experiments, on the relationship of copper and molybdenum intake to copper storage in the liver of sheep have shown that at a molybdenum intake of 0.2 mg. per day, which is a common level under normal conditions, the amount of copper stored in the liver during a period of six months is proportional to the copper intake over the range of 3 to 30 mg. per day. When sheep have a constant copper intake of 8 to 10 mg. per day the effect of molybdenum in limiting copper storage is progressively greater as the molybdenum intake is increased from 0.3 to 20 mg. per day, but increasing the intake to 50 or 100 mg. per day does not have any greater limiting effect under the conditions of the experiment.

(*c*) *Sheath Rot.*—Periodic observations were continued throughout the year on a flock of about 500 wethers in the Western District of Victoria. The incidence of external ulceration around the sheath orifice increased to a high level during the late autumn and winter, when more than 90 per cent. of the wethers showed lesions, fell again during the spring, and was at a low level during the summer. This confirms the observations made during the previous year. The decrease in incidence of external ulceration in the spring was again accompanied by the appearance of internal involvement of the sheath which gradually increased to a maximum of 5-7 per cent. in December and then decreased during the summer either by death, culling, or occasionally by recovery of affected animals.

The influence of male hormone (testosterone propionate) on the course and development of the lesions was studied by giving to 100 animals a single dose of 100 mg. in tablet form implanted subcutaneously. Over the following six months the incidence of lesions in this group remained at a considerably lower level than in a group of 100 untreated animals kept as controls.

(*d*) *Fleece Rot.*—Largely as a result of the high rainfall during the last three years observations have been continued on the incidence of fleece rot at the F. D. McMaster Field Station. The wet summer of 1950 again caused a high incidence of the condition in the sheep on the property. This high incidence does not appear to be associated with fleece character or conformation, whereas a close association appears to exist between it and other characters, which suggests an hereditary basis of susceptibility. The high incidence, 43 per cent., of the conditions in the strong-wool Merinos at Chiswick Field Station, Armidale, compared with the low incidence of 1 per cent. in the fine-wool Merinos, is a significant finding.

## 16. INTERNAL PARASITES.

(*a*) *Studies on Anthelmintics.*—Further trials on the efficacy of phenothiazine against the large-mouthed bowel worm (*Chabertia ovina*), which occurs in the large intestine of sheep, confirmed previous findings that it is somewhat less effective against this parasite than against the nodule worm. Nevertheless, a dose of 20 g. phenothiazine injected into the rumen of sheep removed 66-97 per cent. of *C. ovina* (average 85 per cent.) from the treated sheep in one trial. Phenothiazine was also less effective against the relatively harmless parasite *Oesophagostomum venulosum*, which inhabits the blind gut or caecum, than against the closely related nodule worm (*O. columbianum*) which is found in the adjoining colon.

Tests with different phenothiazine tablets showed tha their anthelmintic efficiency was affected by the formulation and method of manufacture; tablets in which the phenothiazine particles were aggregated, so tha when the tablets disrupted within the rumen the fragments ranged up to a millimetre in diameter, were of very low efficiency.

The dose of phenothiazine usually prescribed for weaners weighing about 35-40 lb., namely 16 g., was more effective against *Ostertagia* spp. and *Trichostrongylus axei* (the small hair worms occurring in the abomasum) than against species of *Trichostrongylus* in the small intestine. Doubling the dose did not increase efficiency against the abomasal worms but a much greater proportion of *Trichostrongylus* spp. in the small gut was destroyed. When these parasites are present in great numbers the usual doses of phenothiazine may leave a residue of worms which is large enough to prevent recovery, even if the sheep are moved to clean grazing. Under these conditions it is necessary to use larger doses.

Polychlorbenzene in doses of 1 to 3 ml. and hydroquinone in doses of 1 to 3 g. were ineffective against *Haemonchus contortus* when injected into the rumen. Lead arsenate in doses of 0.6 g. appeared to remove *Moniezia expansa* (the common tape-worm of sheep) from 25 weaners treated under field conditions. The sheep were all lightly infested and showed no improvement in body weight after treatment, thus confirming the belief that these parasites are of little consequence to the host unless present in unusually large numbers.

At Armidale no significant increase in infant lamb mortality was observed in a flock with dose rates of phenothiazine ranging from 8 to 25 g. administered within 13 days of the birth of the first lamb. Good control of parasitism was achieved at all rates except at the 8-g. dose.

Over the past two years the seasonal drenching plan recommended by the Division of Animal Health and Production, but omitting one drench with phenothiazine in the winter and adding a drench in December, was put into operation on the western slopes. Control of parasitism, as indicated by faecal examination and inspection of the sheep, has been very satisfactory.

Hexachlorethane was compared with carbon tetrachloride against flukes and round worms in sheep by the use of two accepted dose rates. Toxic effects were produced with both dose rates, and two deaths in fifteen sheep at the higher dose rate. Affected sheep responded to calcium therapy. Carbon tetrachloride produced no untoward effects.

(*b*) *Studies on Resistance to Nematode Infestation.*—The results of further trials concerning the "self-cure" phenomenon, now known to be associated with the sudden intake by infested sheep of large numbers of *Haemonchus contortus* larvae, suggested that "self-cure" may take place irrespective of the age of the existing infestation. In many instances, the establishment of an initial infection appeared to be hindered when a further dose of larvae was administered 5, 10, 15 or 30 days after the original infection. Further observations along these lines are planned, in which larvae of the cattle strain of *H. contortus* will be used for the test dose, and larvae of the sheep strain for the initial infection.

A trial with adult wethers which had been kept on a low plane of nutrition for twelve months showed that sheep under such conditions may be unusually susceptible to the large stomach worms (*H. contortus*) and to black scour worms (*Trichostrongylus* spp.). Some of these sheep were in relatively good condition, weighing 90-100 lb., and others were in poor condition averaging only 50 lb. in weight. Of five sheep in good condition which were dosed with *Trichostrongylus* larvae, two developed heavy infestations but none died; of five in poor condition which were dosed similarly, four developed heavy infestations and one of them died. Of five sheep in good condition which were dosed with *H. contortus* larvae, two developed heavy infestations, one of which was fatal, and of four sheep in poor condition similarly treated, three developed heavy infestations, all of which were fatal. This trial emphasizes the fact that sheep which have come through a drought, even adult animals, are especially susceptible to worm infestation. When the drought breaks, the seasonal conditions foster the parasites as well as the sheep and, as parasites respond to such conditions much more quickly than sheep, heavy losses from worms may result unless effective treatment and management are practised. In another trial, sheep which had developed stong resistance to *Trichostrongylus* spp. were kept on decreasing levels of nutrition and their resistance was tested periodically. It was apparent that individual animals differed greatly. Resistance was lost by some but others retained it even when reduced to a severe stage of malnutrition.

Another attempt was made to examine the effects upon nodule-worm infestations in weaners, of continuous grazing on green oats during the winter months at the McMaster Field Station, but the results were inconclusive because the oat crop was spoilt by seasonal conditions.

Serological studies on resistance and immunity to nematode infestations in sheep have been continued. Several alternative methods of preparing antigen from *H. contortus* were tested but the boiled antigen prepared from larvae proved the most satisfactory. Precipitin tests with positive sheep sera and the use as antigens of the carbohydrate fraction of adult worms or the boiled antigen, gave no reaction. Injection of heat-killed larvae of *H. contortus* into the rumen of infested sheep induced a transitory increase in titre of antibody but "self-cure" did not result. Evidence was obtained that the complement-fixing antibody is transmitted to the lamb from the colostrum of the ewe. Administration to lambs of serum from resistant sheep appeared to give no protection against infestation by *H. contortus* larvae given simultaneously. Examination of adult *H. contortus* at the time of "self-cure" showed no apparent abnormality except that most of the females had expelled their eggs. Injection of histamine into the abomasum did not induce "self-cure". Infested sheep were given repeated subcutaneous and intravenous injections of sterile milk and of horse serum, but "self-cure" did not occur. The reaction of infested "resistant" sheep which had been vaccinated with *S. typhi-murium* was also studied. These several experiments all support the view that the complement-fixing antibody associated with "self-cure" is of a specific nature. However, in some infested sheep the faecal egg count fell sharply when the host was inoculated with *S. typhi-murium* vaccine, although their serum remained negative to *H. contortus* antigen. An explanation of this has not yet been found. It was found that older sheep are resistant to *Trichostrongylus* spp. because of previous infestation and not because of their age. When this resistance was broken down by maintaining them for long periods on very low nutritional levels there was no antibody response to administration of larvae. The effect of positive sera on mature worms and larvae has been studied: no convincing evidence could be found of the formation of precipitates at the buccal or genital orifices. It was found, however, that positive sera reduced the respiration rate of adult *Trichostrongylus* spp. by about 38 per cent., and eggs of *Trichostrongylus* spp., incubated in positive sera with guinea-pig complement, embryonated but did not hatch, whereas with negative sera and complement they hatched normally. The effect on the respiration rate of *H. contortus* was much slighter and its eggs hatched normally in positive serum plus complement.

Studies were made on the effects of infestations with *Strongyloides* spp. and with adult *Oesophagostomum columbianum*.

(*c*) *Epidemiological Investigations.*—Some overseas reports suggested that worms infesting sheep may produce eggs in greater numbers during the spring months. A carefully planned and controlled experiment failed to reveal any evidence of increased egg production by *Haemonchus contortus* or *Trichostrongylus* spp. during the spring.

Epidemiological investigations have continued at Armidale over a period of thirteen years. The stomach worm (*Haemonchus*) picture follows a consistent trend closely associated with climatic conditions, a winter trough, a rise in spring, and peaks in early summer and autumn, punctuated with several "self-cure" periods. The epidemiology of the black-scour worm (*Trichostrongylus*) and the nodule worm (*Oesophagostomum*) has differed somewhat from the generally accepted picture, the worm burden being lower during the winter and higher in the spring and summer. The worm burden with these parasites is influenced by the nutritional status of the sheep, its individual susceptibility, the stocking rate, and the climatic conditions.

Lungworm (*Dictyocaulus*) infestation has been studied in one group of sheep for a period of eighteen months. Maximal infestation occurred within three months of birth but rapidly declined and remained at low levels for the next fifteen months.

(*d*) *Winter Feeding of Weaners.*—The investigation was continued at Armidale. At Cherry Hill, on the granite country, Merino weaners were grazed during the winter months of 1949 on phalaris-clover pasture, Wimmera rye grass, lucerne, green feed oats, and on partly improved natural pasture. Some groups had continuous access to the pasture on crop, some had access for two and a half days, and others for four and a half days per week. Only the phalaris-clover pasture and the lucerne were sufficiently productive to allow the sheep to make a substantial increase in body weight. With the exception of the group having four and a half days per week on the phalaris-clover pasture, all the part-time groups lost weight. No difference in the worm burden of the several groups was established.

(*e*) *Parasite Physiology and Toxicology.*—(i) *The Mode of Action of Phenothiazine as an Anthelmintic.*—Continuation of the investigations referred to in the last Report suggests that the extreme toxicity of phenothiazine to certain nematodes compared with its relative lack of toxicity to the host animal may be due largely to the fact that tissues of the parasite take up phenothiazine at a higher rate than do those of the host. However, the fact that phenothiazine is effective against some nematodes and not against others cannot be due to differences in their rate of uptake because it was found that certain susceptible and non-susceptible species had a very similar rate. Phenothiazine appears to enter the parasites mainly by absorption through the cuticle and to a much lesser extent by ingestion. Work was begun to determine whether phenothiazine itself or one of its derivation products is responsible for the expulsion of susceptible worm parasites. Some differences have been detected in the metabolism of parasites which are, and those which are not, susceptible to phenothiazine. In continuation of this work the nitrogen metabolism of nematode parasites is being investigated; in non-nutrient media in which bacterial growth is limited by the presence of penicillin and streptomycin the parasites excrete ammonia, urea, and very small quantities of uric acid. The source of the ammonia is being sought.

(ii) *The Uptake of Phosphates by Host-tissues and by Nematodes in Sheep.*—This was determined after injecting radioactive phosphorus (as sodium acid phosphate) into the abomasum and intravenously in sheep. The small intestine absorbed more phosphate than the abomasum which, in turn, took up more than the rectum. The uptake was much higher after intravenous injection than after injection into the abomasum. The fluid in the lumen of the gut showed negligible uptake from intravenous injection but its content rose steadily after injection into the abomasum. *Trichostrongylus* spp. took up about three times as much $P^{32}$ as the small intestine (in which it resides) and much more than any other worm tested, when the sheep was injected intra-abomasally; its uptake was almost as great after intravenous injection. These facts strongly suggest that *Trichostrongylus* spp. are tissue feeders and that they can also absorb phosphate through their cuticular surface. The large stomach worm, *Haemonchus contortus*, which inhabits the abomasum, took up about as much $P^{32}$ as did the abomasal tissue, both after intravenous and intra-abomasal injection. This suggests that *Haemonchus contortus* is also a tissue feeder but that it absorbs little or no phosphate through its cuticle. The nodule worm, *Oesophagostomum columbianum*, also appears to feed on the host's tissues rather than on gut contents, as it took up much more phosphorus after intravenous injection than after intra-abomasal injection. The possible significance of these results in relation to phosphate metabolism in heavily infested sheep needs consideration.

(iii) *The Mode of Action of Fluoracetic Acid.*—This substance actively inhibits respiration and citrate utilization by the tissues of nematode parasites. Its action on pigeon muscle, in these respects, is weak under ordinary conditions but at high oxygen tensions, or after addition of cytochrome *c*, is much increased. It appears that the action of the drug is associated with the oxidation-reduction potential of the system examined; at $E_h$ values of less than + 50 mV. inhibition by 0.01 M fluoroacetate is weak, whereas at about + 150 mV. inhibition is complete.

(iv) *Studies on the Nucleic Acid Metabolism of Malaria Parasites in Relation to Mitotic Inhibition and Chemotherapy.*—This work was commenced towards the end of the year and methods of cultivating malarial parasites *in vitro* are being examined.

### 17. External Parasites.

(*a*) *Control of the Foot Louse* (Linognathus pedalis) *of Sheep.*—This parasite was successfully eradicated from a small flock of Romney Marsh sheep by 0.007 per cent. gamma BHC, used in a footbath contained on the floor of a power spray unit.

(*b*) *The Itch-mite* (Psorergates ovis) *of Sheep.*—Dipping in lime-sulphur will control itch-mite, but it has certain disadvantages. Accordingly, work was carried out to determine whether BHC would give effective results. Concentrations ranging from 0.007 to 0.056 per cent. gamma isomer BHC were tested as suspensions with and without additional wetting agents, in "phenolic" emulsion and in oil emulsion. All these preparations failed to eradicate the mite although the higher concentrations reduced the populations to a very low level. Other insecticides which proved ineffective when tested by the "patch" method against *P. ovis* on infested sheep, were 1.0 per cent. DDT, 0.1 per cent. toxaphene, 0.01 per cent. parathion, and 1.0 per cent. copper sulphate. A proprietary product, "Tetmosol", gave promising results but would be too expensive in the concentrations required. Colloidal sulphur, at 1.0 per cent., also gave promising results.

(*c*) *The Use of Insecticidal Fogs for Control of Ectoparasites of Sheep.*—Several small-scale tests showed that insecticidal fogs may have value for this purpose. The fog was generated by a Todd Insecticidal Fog Applicator (T.I.F.A.) from a suitable oil containing 20 per cent. gamma BHC or 10 per cent. *pp′*-DDT. These fogs killed all lice on small groups of sheep exposed to them for a few minutes just after shearing, but were ineffective when the wool was longer. In the only large-scale field test with which we were associated the method failed because lice survived in patches of wool about 1 in. to 1.5 in. in length which imperfect shearing had left. Moreover, the conditions under which the sheep were fogged were unsatisfactory. Unless such difficulties can be overcome it will not be practicable to use fogs for the control of lice on sheep. Among Merino sheep particularly, some longer wool is almost always left on a proportion of the sheep. Similar fogs applied to the sheep in long wool reduced ked populations remarkably. There has been no opportunity as yet to test them against keds in recently shorn sheep. Much remains to be learnt about use of fogs not only to discover an effective and safe concentration of insecticide but also to determine the best way to use them under the extremely variable conditions which are met in practice.

## 18. Sheep Blowfly.

(*a*) *Protection against Body Strike.*—(i) *Field Trials.*—Trials to determine the value of DDT and BHC preparations in the prevention of body strike in sheep were carried out by the Division of Animal Health and Production in New South Wales. Results of trials carried out in 1949 showed that a DDT preparation applied to sheep at a concentration of 2 per cent. *pp'*-DDT at the rate of 0.36 gallon per sheep, and a 0.1 per cent. gamma isomer BHC preparation at the rate of 0.38 gallon per sheep, gave complete protection against body strike under conditions of moderate fly activity. Investigations in 1950 aimed at testing whether adequate protection could be obtained by the same treatments under severe fly-wave conditions, by reduced concentrations, or by reduced quantities of the same concentration. Attempts were also made to find out whether it were necessary to obtain penetration of the fleece, or whether a surface coating of the insecticide were sufficient. These experiments were carried out in the Narromine district under extreme conditions.

A spray dip was adapted for use in these Narromine trials and sheep were treated as groups. A 1 per cent. DDT preparation was applied at the rate of 0.25 gallon per sheep, and of this 0.17 gallon remained on the sheep. On the first few days following spraying, 431 points of rain were recorded and a severe wave of body strike was present in the area. The flywave abated ten days later and at 24 days 2.4 per cent. of body strike had occurred in the treated sheep compared with 12.8 per cent. of strike in untreated controls running in the same paddock. During the same period 29.5 per cent. strike occurred in untreated controls running in an adjacent paddock. In the same trial, 2 per cent. DDT applied at the same rate per sheep gave no greater protection, but where the amount retained on the sheep was increased to 0.23 gallon per sheep there was an indication of greater protection. The lower record of fly strike in sheep running with the DDT-treated sheep compared with the strike in similar sheep in an adjacent paddock suggests that the fly population and activity are considerably reduced in the vicinity of DDT-treated sheep.

Fleece rot was usually active in the sheep which were struck. The immediate area on which fleece rot could be observed remained wet with very fine globules of moisture for several days longer than the adjacent apparently unaffected area. The presence of moisture and warmth at this point favoured the development of a strike.

The preconditioning of the tip of the fleece with water several minutes before the application of 0.25 gallon of insecticide enabled better penetration to be obtained with practically no run-off. Increased volume seems to be more important than increased concentration above 1 per cent. DDT and heavy rain following treatment did not reduce the effectiveness appreciably.

Some BHC preparations at 0.05 per cent. gamma isomer and 0.1 per cent. gamma isomer were used on other groups but circumstances did not allow a comparison with DDT.

Further trials were carried out in co-operation with the Queensland Department of Agriculture and Stock and the Division of Entomology. A severe wave of body strike occurred in the spring in the Charleville district and the opportunity was afforded of carrying out a trial there. The results obtained showed that under conditions of intense fly activity good protection may be given by both insecticides for a period of at least four to five weeks. Treatment consisted of applying a fairly coarse spray of the insecticide under 100-150 lb. pressure over the area from behind the ears to and including the tail, with a width of about 10 inches in the region of the back. The *pp'*-DDT was applied at a concentration of 1 per cent. and at rates of $\frac{1}{4}$ and $\frac{1}{2}$ gallon per sheep. BHC was applied at similar rates per sheep and at a concentration of 0.05 per cent. gamma BHC. No differentiation in effectiveness could be made between the two insecticides or between the rates at which they were used. A group of untreated controls running with the treated sheep was also protected.

An unusually severe and prolonged body-strike wave occurred throughout central and north-west Queensland as a result of abnormal summer and autumn rains. Total losses in general were extremely high. Owing to the flooded conditions of the country, graziers were unable to muster their flocks and trials could not be arranged. However, the Department of Agriculture and Stock found that where DDT and BHC had been used early in the outbreak, good protection had been obtained and losses were comparatively small. Where, however, the incidence of strike had increased to a fairly high figure before treatment was undertaken, losses were much more severe.

A trial, in anticipation of an autumn outbreak, was commenced in the Stanthorpe-Texas area in April. Strikes have not been recorded to date in either the treated groups or controls.

(ii) *Tests with Insecticidal Fogs for the Prevention of Body Strike.*—The two Divisions in co-operation also carried out at Canberra an insectary test on insecticidal fogs for the prevention of body strike. Groups of sheep were exposed to fog containing 2 per cent. gamma BHC and 10 per cent. *pp'*-DDT. Other groups were sprayed from poll to rump with 0.05 per cent. gamma BHC and 1.0 per cent. *pp'*-DDT at the rate of 1 gal. per sheep. The treated sheep, together with some controls, were subjected to approximately 1 inch of artificial rain from the nineteenth day. On the nineteenth day and at intervals thereafter sheep from each group were placed in an insectary with a dense population of ovigerous *Lucilia cuprina* (the primary sheep blowfly of Australia), and plugs moistened with an attractant solution were inserted in the fleece. Under these severe conditions the fogged sheep showed no evidence of protection even at the nineteenth day, whereas the sheep sprayed with BHC were protected up to 33 days and those sprayed with DDT up to 54 days. A 10 per cent. *pp'*-DDT fog was also tested, under field conditions, at the McMaster Field Station, on 40 sheep. As a control 40 similar sheep which remained untreated were run in an adjoining paddock. Strikes occurred in both groups within a few days and during the month following treatment there were 15 strikes among the treated sheep compared with 22 among the controls.

(*b*) *Lamb-marking Dressings.*—Difficulties have arisen in obtaining adequate supplies of one of the commercial citronella oils for the manufacture of marketable quantities of the lamb-marking dressing "Borocit". The present price of pure Ceylon oil of citronella is such as to prevent its use in a commercial dressing. Two commercial citronella products have been tested during the year, but gave very variable results. These are by-products of pure citronella oil from which geraniol and certain other derivatives are extracted, and as the original source of oil is often doubtful, it seems that it will not be possible to manufacture a commercial dressing from commercial citronella products which can be expected to be consistently highly efficient. Attention is now being directed primarily to phthalate preparations.

### 19. Other Investigations.

(*a*) *Neo-natal Mortality in Lambs.*—Observations on lambing ewes at Chiswick Field Station in 1948 suggested that among important factors influencing the ability of ewes to rear their lambs were the condition of the ewe at the time of lambing, the mothering ability of the ewe, and the vitality of the lamb at birth. Accordingly, work on lambing losses in 1949 was planned mainly on an animal husbandry basis to include investigations on the feeding of ewes during late pregnancy, the effect on marking percentages of different methods of crutching ewes prior to lambing, late lambing "off-shears", and pen versus paddock lambing. A small trial was also conducted to investigate the incidence of pre-natal foetal death. Owing to the abnormally wet weather experienced during late winter and spring the pen versus paddock lambing comparison had to be abandoned. There was considerable interference with the trial on the feeding of ewes in late pregnancy but some results were obtained. The neo-natal mortality ranged from 4 to 16 per cent., the majority of deaths occurring during periods of heavy rain. The heaviest losses (16 per cent.) were in the groups in the green oats paddock, which was completely devoid of shelter.

In experiments designed to compare late with earlier lambing the mortality in the late lambing groups was only 6 per cent. of lambs born, and these were lost mainly during periods of heavy rain. Despite these negligible losses the marking percentages were much lower than in the early lambing groups. The number of dry ewes and ewes not served was appreciably higher than in similar ewes mated six weeks earlier. The marking percentage in ewes lambing "off-shears" was 63 per cent. compared with 58 per cent. in ewes lambing in the wool.

In the observations on pre-natal foetal death there was no evidence of multiple conception in Merino ewes with subsequent re-absorption of a second foetus in two groups of 22 ewes. One ewe aborted at the sixty-fifth day of pregnancy.

Records have been kept of the lambing data for 1948 and 1949 of two groups of ewes which were originally mated as maidens in 1948. In both groups the ewes which reared a lamb in the first year had an appreciably higher percentage of lambs reared in the second year than ewes which either lost their lamb or failed to lamb as maidens.

(*b*) *Survey of Fine-Wool Production.*—This survey is particularly concerned with the performance and production of the major strains of fine-wool sheep in the more important pastoral areas of eastern Australia. It is complementary to the "strain trials" (*see* Section 13 (*g*) above). Field work and reports for New South Wales have been completed and the survey officer has transferred his activities to Queensland.

## VIII. CATTLE.

### 1. General.

The Organization's work on dairy and beef cattle problems has been carried out within the Division of Animal Health and Production (mainly in the Animal Health Laboratory, Melbourne, and in the Veterinary Parasitology Laboratory, Queensland), and is described in Sections 2, 3, 5, and 6 below.

The Division of Entomology has been concerned with work on the cattle tick outlined in Section 4 below. The work of the Division of Plant Industry on pastures (*see* Chapter III., Sections 2-10) is also of importance to the cattle industry.

### 2. Cattle Diseases.

(*a*) *Pleuropneumonia of Cattle.*—Further attempts were made to detect antigenic differences between strains of the causal organism. Each of two cows was infected by subcutaneous inoculation with a recently isolated virulent epidemic strain. Cross complement fixation and agglutination tests on their sera with antigens prepared from the two strains and from six others failed to reveal evidence of antigenic differences.

The effect of certain antibiotics upon strains of the causal organism is being examined. It has been found that penicillin is without bacteriostatic or bactericidal effect even in concentrations of 1,000 units per ml.; on the other hand, streptomycin or dihydrostreptomycin is bacteriostatic in a concentration of 0.1 mg. per ml., but is not bactericidal even at ten times greater concentration.

During the year 475,000 doses of vaccine were forwarded to the distributing centres in Queensland, Northern Territory, and New South Wales. Complement-fixing antigen was provided cost-free to Government authorities in Victoria, New South Wales, Queensland, and Kenya, and to U.N.E.S.C.O. The amount of culture growth used for this purpose was equivalent to 200,000 doses of vaccine and the production cost was appreciable.

(*b*) *Tuberculosis of Cattle.*—The study of diagnostic tests was continued in the early part of the year, but had to be restricted to allow other work to proceed. Observations were made only on cattle in which the interpretation of routine tuberculin tests was especially difficult for the statutory testing authorities; in such instances further tests were prescribed and performed after consultation. The application of the short thermal test, described in previous reports, continued to prove a valuable aid in differential diagnosis. Within the Division, investigational work was directed chiefly toward the comparative study of tuberculins and of sites for inoculation; cattle artificially sensitized with tubercle bacilli of the avian type or mammalian types, or with the causal organism of Johne's Disease, were used for that purpose. The synthetic-medium mammalian tuberculins prepared by the Commonwealth Serum Laboratories for use in Australia compared very favorably with the P.P.D. tuberculins prepared at Weybridge for use in the United Kingdom; all were tested in a dose of 0.1 ml. intradermally in the side of the neck. A batch of synthetic-medium avian tuberculin prepared by the Commonwealth Serum Laboratories also proved very satisfactory in testing cattle sensitized with either avian tubercle bacilli or *Mycobact. johnei*. It is considered that the results of tests performed in the neck site, with measurement, are better than those of tests performed in the intracaudal fold in accordance with the routine method adopted in Australia. However, practical difficulties associated with the neck site are apparent under Australian conditions and its usefulness is, therefore, limited. Serum samples from these artificially sensitized animals were supplied to the Commonwealth Serum Laboratories for testing by complement fixation in the presence of red blood corpuscles sensitized by polysaccharide extract derived from the several mycobacteria. The results are of interest, but problems of lack of complete specificity will need to be studied before any practical application becomes possible. In the laboratory the short thermal tuberculin test was studied in guinea-pigs and other small animals.

(*c*) *Mastitis in Dairy Cattle.*—The residue of the original experimental herd, which is now maintained as a producer unit, is still under supervision. Studies were continued on the value of antibiotics in eliminating udder infections. The work on procaine penicillin referred to in the last Report was extended and the findings then reported were confirmed. Staphylococcal infections continue to be difficult to control. Following reports from the United States of America that a combination of penicillin and streptomycin was effective, even in a single dose, in eliminating staphylococci from the udder, trials were carried out in the field with a combination of 100,000 units of penicillin and 0.1 g. dihydro-streptomycin. These trials have failed to confirm the good reports from the United States of America; in most clinical cases staphylococcal counts were reduced to very low levels or were virtually eliminated, but they increased rapidly again when treatment ceased. Subclinical infections responded more satisfactorily but even with these only about a third were eliminated.

An outbreak of mastitis was investigated in which the evidence suggested that bacterial agents were not responsible. The disease took the form of clots and severe depression of milk secretion, frequently in all four quarters simultaneously. It was transmitted by intramammary inoculation and some spontaneous transmissions occurred among uninoculated cattle cohabitating with them. The investigation is proceeding.

The value of quaternary ammonium compounds as disinfectants on teat surfaces and on milking utensils was compared with that of sodium hypochlorite. In the recommended concentrations, the quaternary ammonium compounds were less efficient for sterilizing milking utensils under normal shed conditions than was sodium hypochloride (approx. 1,000 parts per 1,000,000 free chlorine). Used as a cream or jelly, one of the compounds proved very effective when a contact period of three hours was allowed. These tests confirmed previous experience that hypochlorite is outstandingly effective when a short contact period is obligatory.

Studies were continued on the haemolysis of ox blood media by staphylococcal $\beta$ toxin and its inhibition by an agent from a diphtheroid bacillus. Inconsistencies were traced to the chance use of ox blood containing antibody against $\beta$ toxin and the necessity for selecting antibody-free blood was demonstrated.

(*d*) *Bruceliosis in Cattle.*—Reference was made in the last Annual Report to a field trial of immunity produced by the subcutaneous inoculation of 5.0 ml. of "Strain 19" vaccine as compared with that resulting from 1.0 ml. inoculated at the tip of the tail. During the year the experiment reached the "challenge" stage, with approximately 40 animals in each group and a similar group of controls. The numbers were reduced from the expected 60 per group by temporary infertility, which was evident in many animals of all groups during a mating period of three months. The fact that the non-vaccinated control group was affected equally with the vaccinated groups is a useful indication that factors other than vaccination were responsible, especially in view of the tendency for owners, in several countries, wrongly to suggest that vaccination produces a temporary infertility. The experiment is proceeding satisfactorily, and 25 per cent. of the control group have already aborted whereas only one of the 80 vaccinated animals has aborted. Conclusions regarding the degree of protection resulting from each method of vaccination cannot yet be drawn.

In the laboratory, the developing chick embryo was found very useful in the routine examination of material suspected of containing *Brucella abortus.* These experimental groups of cattle of known history provide an excellent source of material for special investigations; for example, useful information has already been obtained on the value of the "ring test" as evidence of infection in an individual cow or in a herd by the use of bulk milk. It is considered that the "ring test" will prove to be of very great practical value in the diagnosis and control of brucellosis. The influence of "Strain 19" vaccination on the reaction of the milk of cattle free from the disease is under investigation.

(*e*) *Haematuria vesicalis.*—The examination of the aromatic amine excretion of cattle has been continued, and paper chromatography has assisted in the identification of some of the individual compounds present. Some progress has been made in developing methods to identify and determine aminophenols if present in urine.

(*f*) *Anaplasma centrale.*—The strain of *A. centrale* has been further propagated in calves, and infective blood was made available to Government authorities in Queensland. After preservation in the dry-ice box at approximately —80°C., 1 ml. of blood, taken at the height of infection, was still able to produce typical infection after 739 days.

(*g*) *Other Diseases.*—An outbreak of abortion on one of our field stations was investigated. There was no evidence of brucellosis or of trichomouriasis but a highly pathogenic strain of the paracolon group of bacteria was isolated in pure culture from aborted foeti. Agglutinins to this strain were present in the blood serum of several cows in the herd.

### 3. INTERNAL PARASITES.

(*a*) *Epidemiology of Parasitic "Gastro-enteritis" of Cattle.*—These studies have been continued and sufficient progress has been made to permit certain conclusions to be drawn. Infestation with the species of importance in the areas under investigation, namely, *Haemonchus contortus, Bunostomum phlebotomum, Cooperia* spp. (*C. punctata* and *C. pectinata*), and *Bosicola radiatum,* may take place at any time of the year, for at no time in coastal Queensland does the temperature become low enough to interfere seriously with the development of the eggs and the activity of the infective larvae. Furthermore, it would seem that eggs in a dung pad are able to complete their development and the larvae to reach the infective stage in the absence of rain, the moisture present in the dung pad being adequate for this purpose. Unless rain falls, however, the majority of the larvae appear to be unable to move out of the dry pad, and thus cannot become free to infest cattle. Outbreaks of *H. contortus,* for which extremely large numbers of larvae are necessary, require a monthly rainfall of at least five inches. Rainfall requirements for outbreaks of *Cooperia* spp. infestation to appear are less than this; it seems that *Cooperia* larvae may become free to infest cattle under conditions unfavorable to *H. contortus.* Heavy infestations of *B. phlebotomum* require an additional "overcrowding" factor, such as is seen on dairy farms. These are all summer-rainfall species and the adults occur in greatest numbers in the autumn and winter.

*Ostertagia* spp. (*O. ostertagi* mainly) and *Trichostrongylus axei* are winter-rainfall species, and their relative unimportance in the summer-rainfall areas under investigation is considered to be due mainly to their lack of tolerance of the high temperatures of these areas.

There is good evidence that an immunity to infestation by *H. contortus, B. phlebotomum, Cooperia* spp., and *B. radiatum* develops very early in the life of the animal and infestations thereafter remain on a low plane. The position regarding *Ostertagia* spp. and *Trichostrongylus axei* is not so clear. It is believed that an immunity to these two species may ultimately appear, but may frequently be considerably delayed. The immunity to *B. phlebotomum* is most interesting in that it appears to be an almost absolute immunity. Under conditions where extremely large numbers of larvae are available, the development of immunity may be frequently so delayed that animals may be seriously affected and even die. The influence of nutrition on the development of this immunity is being investigated, as is also the possibility that treatment delays its onset.

These studies have as their main objective the control of this disease, and valuable information is becoming available concerning the influence on outbreaks of such factors as calving season, treatment, harrowing the pastures, the use of permanent pastures for calves only, allowing the calves to feed with adult cattle, nutrition, and calf-pen hygiene.

Observations on the relationship between the presence of antibodies and the degree of infestation have been continued in co-operation with the McMaster Laboratory. Although it is too early yet to formulate any conclusion, it is apparent that the relationship between antibody presence and infestation is not as clear-cut as it is in sheep.

(*b*) *Value of Egg Counts as a Measure of Helminth Infestation in Cattle.*—Egg counts have been used throughout the epidemiological studies to study fluctuations in helminth populations and also as a measure of the degree of infestation, particularly in relation to outbreaks. It is well known that egg counts may be influenced by a number of factors, two of which have been studied, namely, the consistency of the faeces and the weight of the animal in relation to its faecal output. Correction factors for consistency of faeces do not appear to be necessary. Factors which correct for increased faecal output have been calculated. A special harness and faecal bag have been designed for measuring faecal outputs. In outbreaks, it has been found essential to sample many animals, at least 25 in beef herds and all calves in the average dairy herd, before attempting a diagnosis. The winter and spring of 1949 were particularly favorable to outbreaks among dairy animals. Many beef herds were also affected shortly after weaning and following a rainfall of 6 to 7 inches in October.

As a result of these investigations and from previous experience, it is concluded that the following egg counts indicate marked pathogenicity: In *H. contortus,* a count of 1,000 per g. in animals of six-twelve months and older is serious, 1,500-2,000 very serious; a count of 500-700 is on the borderline and can be serious if large numbers of other species are present, particularly *B. phlebotomum* (300 per g.) or *B. radiatum* (300-500 per g.). In *Cooperia* spp., a count of 4,000 to 5,000 per g. does not appear to be serious even in animals two-three months old; 15,000 to 20,000 eggs per g. in animals three-four months old are definitely pathogenic. In *B. radiatum,* 750 to 1,000 eggs per g. or more are definitely serious in an animal twelve months old; but if *H. contortus* (500-750 per g.) or *B. phlebotomum* (300 per g.) is also present then a count of 300 to 500 is pathogenic. In *B. phlebotomum,* a count of 500-800 per g. is pathogenic in animals of any age; over 1,000 per g. is very serious; 300 per g. is pathogenic when *H. contortus* (500 to 750 per g.) or *B. radiatum* (300 to 500 per g.) is present.

(*c*) Fasciola hepatica *and* Echinococcus granulosus.—A survey to determine the distribution and importance of these parasites is being carried out in co-operation with the Queensland Department of Agriculture and Stock. The information sought is being furnished by Stock and Slaughtering Inspectors throughout the State as a monthly routine which will continue for a period of twelve months.

(*d*) *Paramphistome Flukes of Cattle.*—Further studies have been made on the identification of the species present in Australia. Three species have been recorded elsewhere, namely, *Paramphistomum cervi, P. explanatum,* and *P. cotylophorum.* It has now been established that neither *P. cervi* nor *P. explanatum* occur in Australia and that the species previously identified as *P. cervi* is *Calicophoron calicophorum.* In addition to *C. calicophorum* and *P. cotylophorum* there appears to be a third species with close affinities to *P. cotylophorum.*

Information has been obtained on the distribution of these species in Australia, and although they have been reported from all States except the Northern Territory, they appear to be most prevalent in coastal and subcoastal Queensland and New South Wales. The common species is *C. calicophorum.* Studies on their life histories show that the intermediate hosts of *C. calicophorum* and *P. cotylophorum* are the planorbid snails *Glyptanisus gilberti* and *Segnitilia alphena* respectively. The maturity period in sheep and cattle, according to experimental infestations, varies from 50 to 63 days for *P. cotylophorum* and 68 to 87 days for *C. calicophorum.* The conditions requisite for the experimental infections of the snail intermediate hosts are being investigated, but in preliminary trials cercaria of *P. cotylophorum* were shed 57 days after infection.

Dissections of snails from field populations indicate that infestation may be seasonal, the infection rate being heaviest in July (43 per cent.) and at its lowest during the summer. However, snails are most plentiful during the winter and difficult to find during the summer. Outbreaks of paramphistomiasis are seen only during the late autumn and winter.

The bionomics of the snail intermediate hosts are also being studied, both in the field and in aquaria in the laboratory.

Monthly egg counts on calves at Pimpama indicated that the flukes reaching maturity in May to June 1949 attained their maximum egg output in September to October. The count declined thereafter, was zero in March, 1950, and then increased again.

Severe outbreaks of paramphistomiasis occurred among sheep at Guyra, New South Wales, in April, 1950, and among calves in the Casino district, New South Wales, in July, 1949.

(*e*) *Closure of Oesophageal Groove in Cattle.*—In view of the failure of phenothiazine against *Bunostomum* and *Cooperia,* it became essential to study ways of bringing about closure of the oesophageal groove, so that the value of anthelmintic drugs such as tetrachlorethylene could be assessed. It was found that doses of 50 g. and 100 g. of glucose into the abomasum caused a two- to three-fold rise in blood glucose within an hour of administration. This rise was not observed when the glucose was given by flank puncture into the rumen or as a drench. Glucose is being used as an indicator of the value of various substances in stimulating closure of the oesophageal groove.

(*f*) *Treatment of Calves for Worms.*—Trials with phenothiazine and hexachlorethane were commenced, mainly to ascertain their value against hookworm, *Bunostomum phlebotomum.* In trials with phenothiazine, dose rates of 0.1, 0.2, and 0.3 g. per lb. body weight were administered by flank puncture into the rumen. The lowest dose rate proved effective against *Haemonchus* only, and any reduction in the egg counts of *Ostertagia, Trichostrongylus, Bunostomum,* and *Cooperia* was only temporary. No *Bosicola* was present. The dose rate of 0.2 g. per lb. body weight did not noticeably increase the efficiency against these species, except perhaps against *Trichostrongylus.* A further increase to 0.3 g. per lb. body weight showed little improvement, but this dose rate proved highly toxic. Two animals developed severe eye lesions, culminating in blindness.

Thus phenothiazine appears to be of use in cattle mainly against *Haemonchus* and *Bosicola.* In therapeutic doses given into the rumen, it is useless against *Bunostomum, Cooperia, Ostertagia,* and probably *Trichostrongylus.* Whether its efficiency against these species can be improved by direct passage into the abomasum is being explored.

Controlled trials with phenothiazine were also carried out among beef calves seriously infested with *Haemonchus* and *Bosicola.* Splendid results were obtained with a dose by mouth of 1 oz. for an animal twelve months old.

In trials with hexachlorethane, ten calves six months old were given by mouth 20 g. of this drug as a suspension. The dose was highly effective against *Haemonchus,* but showed no efficiency against *Trichostrongylus, Cooperia, Bunostomum,* or *Bosicola.*

### 4. Cattle Tick.

(*a*) *Bio-assay Tests.*—Laboratory studies were continued to determine as far as possible the relative effectiveness of potential acaricides before undertaking the cumbersome and expensive process of testing them on infested cattle. Only two stages of the cattle tick are suitable for laboratory tests, the larval tick before it fastens on to a bovine, and the adult female tick after it drops from the host. The remaining stages depend for their existence upon more or less constant attachment to living cattle. Larval ticks are difficult to handle under laboratory conditions, but it is possible to obtain some measure of the effect on them of dipping fluids and dried deposits of toxicant, such as they would encounter when invading the skin of a recently-dipped beast. Adult female ticks are easier to handle in the laboratory, and for this reason they have been used in most bio-assay work this season.

Some acaricides which do not actually kill female ticks dipped in them are nevertheless just as useful, for they prevent females from laying viable eggs. For this reason the various acaricides tested have been evaluated in terms of their ability to prevent the oviposition of viable eggs rather than in terms of their direct lethal properties.

Bio-assay tests were carried out with a number of chlorinated hydrocarbons and organic phosphates. As a result of this and previous work it has been possible to divide potential acaricides into three main classes—

- (i) Those highly effective in preventing female ticks from laying viable eggs, but leaving a deposit which kills the invading larval ticks for only a comparatively short period after drying (for example, arsenic, parathion, and BHC).
- (ii) Those which are comparatively ineffective in preventing the laying of viable eggs, but which leave a long-lasting deposit of high toxicity to larval ticks crawling on it (for example DDT).
- (iii) Those highly effective in preventing female ticks from laying viable eggs, and also leaving a long-lasting deposit of high toxicity to larval ticks. (Chlordane, toxaphene, and dieldrin will probably be included in this class, but further study is needed to determine their persistency and the hazards of their use on warm-blooded animals.)

(*b*) *Chemical Estimation of Organic Acaricides.*—Methods for estimating organic acaricides were further refined during the year.

The Schechter method of analysis detects as little as 10 micrograms of DDT. As an illustration of the sensitivity of the method, it has been employed during the past year to detect the presence of DDT on cattle hair samples taken 35 days after dipping, when only very minute amounts remain. The method is also being used to estimate the amount of DDT in the tissues of animals which had been anointed weekly with DDT in oil for three years in the course of a toxicity experiment. Although clinical symptoms of DDT poisoning were not observed in the cattle, and other methods of DDT analysis gave negative results, the Schechter method demonstrated the presence of DDT in some of the tissues.

Several methods of estimating the gamma isomer of benzene hexachloride are known, but most attention has been devoted during this year to the polarographic method. So far, however, estimations of known concentrations of gamma isomer have been unsatisfactory, and further work is being carried out.

Methods employed in estimating the newer insecticides such as chlordane and toxaphene have been based on the amount of chloride found after breaking down the molecule by refluxing with metallic sodium and isopropyl alcohol.

It has been possible to estimate the organic phosphate acaricides only on the basis of total phosphate content, which limits the value of the estimate because of the presence in the compounds of large amounts of phosphate of little toxicity.

Refinement of these methods of analysis will be useful in furthering the knowledge of the persistency of toxicants on cattle and their stability in dips. It is also desirable, in toxicological studies, to be able to estimate the amounts of acaricides actually absorbed into the bodies of ticks.

(*c*) *Biological and Ecological Studies.*—(i) *Sampling of Larval Tick Populations in the Field.*—A considerable amount of attention was given to this subject during the year because of its importance in future tick population studies in pastures. Variations in density and apparent density may be affected by a number of factors, including seasonal changes and pasture management methods, which would become important in estimating the progress of a tick eradication campaign involving the use of acaricides. Various sampling techniques have been tried, but so far with such limited success that it is still possible only to demonstrate the presence or absence of larvae in a pasture, and not to make a reliable estimate of mean population.

(ii) *Ecology of the Non-parasitic Stages of the Tick.*—Studies of the non-parasitic life cycle of the tick have been in progress in the Brisbane area since July, 1948. The fertility of the females is high, and the pre-oviposition and incubation periods are short from September to February. From March to July fertility decreases, while pre-oviposition and incubation periods increase. Some of the females which mature in late March to mid-July give rise to larval ticks from the end of August to late October, but the majority do not. The important drop of mature females occurs in early March, for these produce eggs which hatch in June and July, and later females which drop off into the pastures in August. It is these August ticks which are responsible for the late-spring rise in population.

(iii) *Studies of Infestation on Stalled Cattle.*—Great difficulty has been experienced in maintaining a continuous supply of ticks for experimental work. If a larval tick population of known size is placed on an animal, the yield of mature adults is extremely variable, and even on one animal the return may be greater or less than from the preceding infestation. No doubt many factors are involved in producing this effect, but licking appears to be one of them. When cattle are prevented from licking themselves, up to 60 per cent.

of the larval ticks applied to them become adult, but when they are allowed to lick themselves a maximum of 20 per cent. of applied larval ticks survives to the adult stage. The elucidation of the factors influencing the survival is important in interpreting such matters as the use of cattle as samplers of pasture populations, tick immunity in cattle, and the evaluation of the toxicity of insecticides.

### 5. Development of Hybrid Dairy Cattle.

The experimental herd at the F. D. McMaster Field Station has increased to 64 head, made up of 21 animals of the Jersey, Red Poll, Friesian, and Illawarra Shorthorn breeds, 33 animals which are one-quarter Zebu, seven which are three-eighths Zebu, one half-bred Zebu, one three-quarter-bred Zebu, and one pure-bred Zebu.

The two quarter-bred Zebu x Jersey heifers, which gave 214 and 210 lb. of butter fat as junior two-year-olds, have given 239 and 211 lb. of butter fat respectively as junior three-year-olds in 273 days. The full sister of the first heifer commenced her first lactation with a daily average of 21 lb. of milk and with 22 lb. of butter fat for her first 30 days under test.

Observations with respect to rate of milk flow, dairy temperament, heat tolerance, and the other characteristics previously reported have been continued without further developments. During 1950-51 it is expected that twelve additional cross-bred females will be in milk and thereafter data should accumulate more rapidly.

### 6. Investigation of Beef Production in Australia.

(*a*) *Survey of Beef-cattle Production.*—This survey has been continued. During the first portion of the year field work covering the survey of the industry in New South Wales was completed and the data were recorded. Field work was recommenced in May, 1950 to examine the industry in South Australia and Western Australia. During the year a Divisional Report on observations in the Northern Territory was issued for restricted circulation.

(*b*) *Quantitative Carcass Appraisal.*—A system of quantitative carcass appraisal is an essential requirement for experimental work on beef production. Such a system has been developed by an officer working at the Cannon Hill, Queensland, abattoir and has given satisfactory results when tested for repeatability and sensitivity. A detailed report on the methods used is being prepared for publication. Further work on the system and its application to studies of growth and development in beef cattle will be postponed until appropriate experimental animals become available.

(*c*) *Studies of the Bovine Skin.*—The population density of hair follicles and sweat glands in the skin of cattle is now assuming considerable importance as a significant feature in the physiology of climatic adaptation by this species, especially to tropical conditions. Studies of the bovine skin were commenced in September, 1949. Using the biopsy technique developed in earlier work by officers of the Division of Animal Health and Production for studying the sheep skin, some 250 specimens of the live skin of several breeds of beef and dairy cattle have been obtained. The specimens were taken under a variety of conditions of production and environment. Microscopic examination of this material is proceeding. Observations made during the year indicate that only primary follicles, i.e. follicles with an associated apocrine sweat gland, occur in the bovine skin, and that rarely are all follicles occupied by mature fibres, owing apparently to the continual process of hair shedding. Follicle density in mid-side samples of the skin of mature cattle of the British breeds appears to be of the order of 8-10 per sq. mm.

(*d*) *Beef-cattle Feeding Investigations.*—In the last Report reference was made to studies, financed by the Australian Meat Board, which were being made at Talbingo (Tumut, New South Wales) through the helpful co-operation of Mr. G. H. Hooper. The installation of a Toledo clock-face cattle-weighing scales has proved of great advantage as it permits accurate weights to be recorded with a minimum of difficulty. Data and observations during the past year included the quantities of feed required to top-off beef cattle under conditions which preclude topping-off at pasture, the establishment of practical feeding standards for beef cattle under Australian conditions, and the economics of such feeding. Carcasses of steers used in these trials were appraised at slaughter through the co-operation of the Australian Meat Board. A total of 140 Hereford steers, rising two year old, passed through the stalls during the winter of 1949. They entered at an average weight of some 900 lb. and gained about 2.25 lb. per day during the four-week feeding period. A further series of stall-feeding trials commenced in June, 1950. In addition, since June, 1949, 30 Hereford weaner steers at Talbingo have been weighed at four-weekly intervals to establish growth curves on pasture. The considerable volume of data from the first year's work at Talbingo is being analysed and prepared for publication.

Valuable information to supplement nutritional and growth-curve data derived from commercial herds is being obtained from two beef-cattle studs in New South Wales where complete records, including those of body-weight changes, are being kept.

## IX. ENTOMOLOGY.

### 1. General.

The Division of Entomology bears the major responsibility for the Organization's work on insect pests and on the biological control of weeds. However, in association with this Division, some aspects of the control of insects that attack animals are being investigated by the Division of Animal Health and Production (*see* Chapter VIII., Section 4) and some aspects of the control of timber pests by the Division of Forest Products (*see* Chapter XIII., Sections 7 (*a*) and (*c*)).

*Division of Entomology.*—The parts played in insect control by the entomological sections of the State Departments of Agriculture and the Division of Entomology are largely complementary. The important task of advising the primary producer on suitable control measures and of adapting methods evolved elsewhere to local problems of pest control is the prime responsibility of the State Departments. The staffs available to them are seldom sufficient to enable them to undertake long-range or fundamental investigations. The functions of the Division of Entomology, on the other hand, are to investigate important insect problems which affect more than one State and for which known methods of control are either ineffective or inadequate, and to undertake fundamental work. Instead of merely attempting to perfect known methods of control, the Division seeks also to obtain new basic information which may lead to the development of entirely new methods of attack, or to the better employment of existing methods.

As the tasks of destroying termites and protecting structural materials from termite attack, of controlling such pests as the earth mite, the cattle tick, locusts, ants, and pasture cockchafers concern industry in many parts of the Commonwealth, the Division of Entomology has undertaken investigations into these pests. The development of effective control measures is often of such immediate urgency that the better known insecticides are usually tested first, but attention is also given to basic work in the hope that more efficient and lasting methods of control may be evolved.

The biological control of insect or weed pests is a project which concerns large portions of the continent and is an important aspect of the Division's work. Here again not only have new beneficial insects been introduced in an attempt to solve certain pest and weed problems, but basic information has been sought about the effects of parasites or predators on insect or plant populations in relation to physical environmental factors.

The physiological and toxicological studies which constitute an important part of the Division's work focus attention on weak points in the physiological processes of insect pests which might be turned to good use in control practice. The proteins and lipoids contained in insect cuticle and the waxy coverings of many scale insects largely determine the permeability of these protective sheaths, and hence the insects' resistance, to insecticides. By incorporating in insecticidal sprays chemicals that will increase the permeability of insect cuticle or break down the waxy coverings of scale insects, it is hoped to render insecticides much more effective. Likewise an examination of the digestive processes which enable clothes moth larvae to digest wool should lead to improved methods of mothproofing fabrics. Progress in this field also depends upon an adequate knowledge of how insecticides act, and this aspect is receiving attention.

Insect abundance is regulated by a complex set of environmental forces. When artificial control measures are superimposed on the natural balance between an insect pest and its environment, it is difficult to forecast their effect. Laboratory and field studies of populations at present in progress should do much to improve our knowledge of the forces operating in these systems and so enable us to employ control measures more intelligently and, it is hoped, with greater effect.

In every entomological investigation it is of the greatest importance to identify correctly the insects concerned. Only then is the information recorded by the entomologist of real and lasting value, and only then can he draw upon and apply the results already established by others. Realizing the necessity for work in this field, officers of the Division, as well as certain other specialists assisted by the Organization, are giving attention to the taxonomy of the more important insect groups.

## 2. Cattle Tick.

Details of research on the cattle tick are given in Chapter VIII., Section 4. The various aspects to which attention has been given are outlined below.

(*a*) *Bio-assay Tests.*—By means of a laboratory test method several acaricides, including some recently developed substances, have been broadly classified according to their ability to prevent females from laying viable eggs and their residual effect upon larval ticks.

(*b*) *Chemical Estimation of Organic Acaricides.*—More accurate methods of estimating very small quantities of DDT are being developed.

(*c*) *Biological and Ecological Studies.*—Observations on the non-parasitic life cycle of the cattle tick and the behaviour and distribution of the non-parasitic stages in the field have been continued.

## 3. Sheep Blowfly.

(*a*) *Insecticides for Protection against Body Strike.*—Tests were continued on the effectiveness of applying insecticides to the tip of the fleece as a protection against body strike. These mainly took the form of field trials with DDT and BHC preparations and are reported in detail in Chapter VII., Section 18.

(*b*) *Taxonomic Status of the Australian Sheep Blowfly.*—Further work has now shown beyond doubt that the Australian sheep blowfly, *Lucilia cuprina*, is morphologically quite distinct from the English sheep blowfly, *L. sericata,* which also occurs in Australia. The geographical distribution of the two species is different, as are their habitat preference and their degree of attraction to living sheep. Furthermore, hybridization experiments indicate that there is great difficulty in obtaining successful matings between the two. *L. sericata* is comparatively rare in sheep-raising country and does little damage.

It now appears likely that the Australian sheep blowfly was introduced into Australia from Africa or India and not, as was earlier thought, from eastern Asia or the islands to the north of Australia, since the subspecies attacking sheep does not occur in the latter regions.

(*c*) *Studies on the Ecology of the Australian Sheep Blowfly.*—In preparation for further study of the factors influencing the abundance of *Lucilia cuprina,* attention has been given to the design of traps, which are important in investigating the habits and life history of the fly. Improved methods of marking flies are being sought, as the ability to recognize retrapped specimens facilitates the study under natural conditions of important aspects of the biology such as longevity, distance of travel, and fertility.

## 4. Insect Physiology and Toxicology.

Work has continued during the year on a numbe of aspects of insect physiology that should ultimatel lead to a better understanding of vital processes su ceptible to interference by selective insecticides.

(*a*) *Digestion of Wool by Insects.*—Last year it w shown that larvae of the clothes moth *Tineola* diff from certain other insects in possessing the ability t digest the wool protein keratin. A comparison has now been made of the protein-digesting enzymes of the clothes moth and those of other insects. It has been shown that the enzyme from *Tineola* is not specially adapted to its unusual substrate, although the environment in which it functions in the digestive tract is rather unusual.

The tracheal supply of the *Tineola* gut is less abundant than that of most other insects and this may be a significant factor in providing the correct environment in the gut for the digestion of wool.

The problem now under study concerns the sulphur metabolism of the clothes moth larva. It is hoped that these investigations will lead to improvements in methods of moth-proofing wool.

(*b*) *Moth-proofing Tests.*—An improvement in the testing method using inbred clothes moths, now in the eleventh generation, has been effected. The enhanced resistance of fabrics treated with various resins is being investigated in co-operation with the Wool Textile Research Laboratories.

(*c*) *Insect Muscle Biochemistry.*—This study is being undertaken in an endeavour to discover significant differences between insects and mammals in the vital processes leading to muscular activity. Work has now been completed, and is being prepared for publication, on a number of enzymes from the muscles of locusts. These are as follows:—

(i) *Mg-activated apyrase.*—This is a powerful, water-soluble enzyme present in high concentration in the wing muscles but almost absent from the leg muscles. It is responsible for the breakdown of ATP to adenylic acid.

(ii) *Myosin-ATP-ase.*—This enzyme, previously not considered important, has now been shown to have a high activity under the correct conditions, which are quite dissimilar to those under which the mammalian counterpart of the enzyme operates. This ATP-ase, which is attached to the myosin fraction of the muscle, is of equal activity in leg and wing muscles. Insect myosin, however, does not exhibit the other well-known enzymatic activity shown by mammalian myosin, that of adenylic acid deaminase.

(iii) *Inorganic pyrophosphatase.*—This enzyme, which exhibits quite high activity in insect muscle, was isolated in the course of purifying the Mg-activated apyrase. It has been shown to be restricted in choice of substrate to inorganic pyrophosphate.

(iv) *Myokinase.*—This heat-stable and acid-stable enzyme, which is of major importance in mammalian muscle, has been shown to be present in only low concentration in insect muscle. The behaviour of the insect enzyme is similar to that of the mammalian counterpart.

A chemical study of ATP from insect muscle has shown that it is identical with that of mammals.

(*d*) *Examination of Cuticular Lipoids.*—An examination has been made of the secretion covering the white wax scale *Ceroplastes destructor,* which attacks citrus and many other introduced and native trees and shrubs. Information thus obtained on the composition of this waxy covering has suggested new methods of control, which are being tested. Some of the honeydew produced by the insect is included in the waxy covering. This honeydew contains about 3 per cent. of the sugar alcohol adonitol (ribitol), which has so far been recorded only rarely.

A study of the metabolism of the cuticular lipoids of blowfly larvae is in progress.

(*e*) *Cuticular Proteins.*—Proteins from the cuticles of a number of insects have been extracted and examined. Their amino-acid contents have been determined, and also the distribution of free amino groups. The latter groups are of importance, since they react with quinones produced in the body to form the hard and dark cuticles of insects. The hardness of the cuticle is of utmost importance in protecting the insect from mechanical damage and it has an important effect both on loss of water from the body and on the entry of insecticides. Some work has been carried out on the structure of the hardened protein.

(*f*) *pH of Digestive Juices.*—The pH of the digestive juices of insects is one of the important factors influencing digestion and absorption, and consequently has an important effect on the absorption of stomach poisons. In all Lepidoptera which have been examined, whether larval or adult, the midgut digestive juices are alkaline. Since the species examined included nectar-feeding, phytophagous, carnivorous, wool-eating, and wax-eating stages it is clear that the characteristic alkaline reaction of the midgut juices of this group of insects is not dependent upon the type of food ingested.

(*g*) *Histochemical Detection of Metals.*—A test has been developed for the histochemical detection of minute quantities of barium and strontium. This will permit valuable information to be obtained on the regions of absorption in the digestive tract and on the route of elimination of metals. Barium and strontium occur most frequently in the Malpighian tubules, less frequently in the midgut and reproductive organs, and only very occasionally in the hindgut and fat body. It is probable that both elements are absorbed in the midgut of most insects, and it appears that they may be fortuitously accumulated in the body by the mechanisms involved in calcium regulation.

(*h*) *Influence of Nutrition on Reproduction.*—A study of the effects of nutrition on reproduction in sheep blowflies is in progress. Irrespective of subsequent adult nutrition, a significant reduction in the number of ovarioles, and in the number of eggs laid per female, is caused by starvation resulting from overcrowding in the larval stage.

## 5. BIOLOGICAL CONTROL.

Injurious plants or insects accidentally introduced from abroad usually flourish in the absence of the natural control factors which operate in their country of origin. Sometimes, however, it is possible to introduce beneficial insects which are known to control a pest effectively in its native land. Various aspects of weed and insect control by biological means are being actively investigated.

(*a*) *St. John's Wort.*—An intensive field study of the effect of the introduced beetles, *Chrysomela hyperici* and *C. gemellata,* on St. John's wort, *Hypericum perforatum* L., is in progress in the Ovens Valley, Victoria, and the Mannus Valley, New South Wales. These beetles were introduced into Australia some years ago in an attempt to control this noxious weed and by the end of 1947 had shown themselves so effective that a more intensive study of their mode of action seemed warranted.

The environment colonized by the weed in the Ovens Valley, and available for colonization by the insects, may be broadly classified into three categories:—(i) land cleared for grazing and cropping; (ii) land dredged for gold; (iii) land under eucalypt forest or pine plantations. Population studies of the beetles where adequate food was available indicate that, generally speaking, both species survive best in areas cleared for grazing and cropping. Over extensive areas which had been dredged for gold neither species could survive the summer. However, the existence of "islands", relatively favorable to survival, throughout the dredgings frequently enables both species to recolonize the least favorable sections each autumn and winter. Neither beetle normally enters timbered areas in large numbers unless forced to do so by destruction of the food supply outside. This forced entry into the trees occurs each spring and early summer when the insects are in the adult stage. Adults of *Chrysomela gemellata* which enter timber areas appear to desert them very largely before oviposition. The mortality of the low residual population is usually high during the following winter. Adults of *C. hyperici* do not exhibit such a marked tendency to leave timbered sites, but the mortality in the young stages of this beetle in such areas is very high, sometimes as much as 100 per cent. Thus it is apparent that a large part of the total area available for colonization by the insects is unfavorable to both species.

The effectiveness of the beetle attack appears to depend on two factors: the type of wort stand defoliated, and the length of the period of defoliation. It is considered that the susceptibility of a wort plant is related to its age, but it is not always possible to tell from the appearance of plants whether they are young or old. The length of the period during which defoliation continues is very different for the two beetle species. Where *C. gemellata* is present in very high numbers the wort plants may be kept completely defoliated from May until November. Such a long period of defoliation kills virtually all the plants in any type of stand. The maximum period of complete defoliation recorded for *C. hyperici* is from late August until the end of November. The resulting mortality was found to depend on the type of wort stand attacked. Defoliation by adults of either species destroys relatively few plants except in the weak stands under the trees in pine plantations. Such wort plants are in the process of being slowly killed by competition with the pines for light.

The regeneration of St. John's wort in areas where the original stand was destroyed by beetles depends on the establishment of seedlings. If, after the destruction of the wort, the area is immediately occupied by native or introduced pasture species which produce a complete cover, the regeneration of the weed is suppressed. The development of a complete ground cover is frequently achieved by applying superphosphate, and establishing subterranean clover where necessary. In many places colonization by native perennial grasses and other pasture species which could probably suppress wort regeneration is prevented by the grazing of rabbits, which also assist the re-establishment of St. John's wort by scratching and burrowing, thereby providing favorable seed beds. Many such areas, together with extensive areas of gold dredgings which were deserted by the beetles after the original stand of wort was killed, are not being re-occupied by the weed. Some of these areas have been re-invaded by the beetles, but with one exception, it is much too early yet to tell whether the weed will achieve its former abundance and productivity before being destroyed by the insects.

The single exception referred to is an area of approximately 12 acres of cleared land virtually surrounded by trees. This area carried a dense stand of St. John's wort several years ago, and since the original stand was destroyed a crop of seedlings has appeared annually. Most of these young plants are destroyed each year by *C. gemellata.* The surrounding timber has apparently acted as a barrier to migration by this species because of the insect's marked "preference" for laying in cleared areas. For the last three years the wort over the area has been defoliated, first by larvae and then by adults. Each spring the surviving adult beetles have accumulated on the wort plants fringing the trees. After aestivating at the edge of the timber, the majority, apparently, were forced to lay again over the cleared area on the young wort plants which survived the summer. As a result of this sustained attack the weed has been held at a low level of density and productivity.

Large numbers of both beetle species were liberated in New South Wales, Victoria, and Western Australia during the year. In New South Wales and Western Australia, officers of the respective Departments of Agriculture co-operated in this project, whilst in Victoria most of the liberations were made by officers of the Victorian Department of Lands and Survey. Some liberations were made in areas of St. John's wort not previously subjected to beetle attacks, while others were intended to supplement colonies which have already been established. Surveys were continued to find out whether the beetles were becoming established in the earlier liberation sites, and to provide information about the incidence of St. John's wort and the possibility of establishing the insects in other infested areas.

Several trial consignments of the midge, *Zeuxidiplosis giarodi,* which produces galls on the stems of St. John's wort, were introduced from southern France towards the end of the year. In Europe, this species contributes to the successful natural control of the weed and if it shows promise under our climatic conditions, liberations may later be made.

(*b*) *Cabbage Moth.*—In an attempt to control the cabbage moth, *Plutella maculipennis,* two Ichneumonid parasites, *Angitia cerophaga* and *Diadromus collaris.* were introduced to Australia. The process made so far in establishing them in the field has been most encouraging. Laboratory breeding of *Angitia* was discontinued at the end of 1949, as there was every indication that it was well established in the major cabbage-growing areas of most States. *Diadromus* is still proving difficult to breed in large numbers, but despite this, twice as many as last year have been liberated in the different States. However, field recoveries have been reported only from Tasmania and the Australian Capital Territory.

(*c*) *Cabbage Butterfly.*—Several consignments of *Apanteles rubecula,* an important parasite of the cabbage butterfly *Pieris rapae* in Europe, were received from Switzerland. In the comparatively short time since these introductions were made, this species has been successfully bred in large numbers in the laboratory, and field liberations have been made in Western Australia, New South Wales, and the Australian Capital Territory, where the parasite appears to have become established.

(*d*) *Green Vegetable Bug.*—The Tachinid parasite *Trichopoda pennipes* is an important parasite of the green vegetable bug *Nezara viridula* in parts of the United States. Consignments of this parasite were received from Florida late in the season, and attempts are being made to breed it in sufficient numbers for field liberations in the spring.

(*e*) *Red Spider.*—The Coccinellid beetle predator *Stethorus vagans* assists greatly, at times, in controlling the red spider *Tetranychus telarius* in this country. Consignments were sent to California, where it is hoped to establish it in an attempt to control mite infestation there.

### 6. POPULATION DYNAMICS.

A study is being made of the natural forces which determine the abundance of animals. A thorough understanding of how these forces operate is necessary before the best ways of bringing about effective control of pests can be devised, and this is the ultimate object of the present investigations.

The forces which regulate the abundance of animals form a system in equilibrium, which is disturbed when man employs destructive measures; but if such measures are used persistently the equilibrium becomes re-adjusted to them, and there is a tendency for this re-adjustment to counteract the direct effects produced by the measures. Thus, although the general effect of heavy destruction of a pest is to reduce its abundance, this reduction may not be nearly as great as one would expect from a knowledge of the percentage of pest individuals destroyed; and there is both theoretical and experimental evidence that under certain circumstances, continued use of destructive measures may even cause a pest to become more abundant. To achieve the most effective control of a pest, therefore, it is not sufficient merely to devise means of destroying a high percentage of pest individuals; we must also know how to influence the natural system of equilibria in a way that favours the control of the pest. This is true whether we use artificial means of control such as insecticides, or introduce new natural enemies.

The sheep blowfly has been chosen as the experimental animal for the preliminary work on population dynamics because it possesses certain special characteristics making it particularly suitable for experimental work in this field. Using this insect, the various kinds of factors known to influence animal populations are studied separately in order to sort out their individual effects. Later these factors will be studied when operating together, to approximate more closely to natural conditions, but this cannot be done until the individual factors have been studied thoroughly. Already it has been shown that the system of equilibrium is not a stationary one but gives rise to sustained and violent oscillations in populations, even when all conditions, including the rate of food supply, are kept constant. The average population varies with the amount of food and the degree of mortality, but the mortality effects are complex. In experiments, which were otherwise similar, the persistent destruction of half the insects as they reached the pupal stage reduced the average population to about half, whereas the destruction of half the maggots as they hatched more than doubled the adult population. This illustrates the kind of effect that may be produced by introducing a new factor into the equilibrium system that governs populations, but until much more information has been collected it would be unsafe to argue that similar effects would be produced under natural conditions.

To make these investigations possible, it has been found necessary to spend much time in developing new techniques and in designing and constructing new kinds of apparatus.

### 7. Locusts and Grasshoppers.

The year under review has been exceptionally favorable for the multiplication of the Australian Plague Locust, *Chortoicetes terminifera.* Observations carried out from the Trangie field station have shown that a large population of this locust has been built up in the Bogan-Macquarie outbreak area, and that a limited number of swarms have already been formed. In the spring of 1949 a larger expedition than that of the previous autumn visited the Cooper's Creek area in south-western Queensland, and discovered many swarms operating in the vicinity of the flooded country along the Creek. Swarms were also observed in the neighbourhood of the Bulloo Overflow in north-western New South Wales, an area which had been suspected of being a minor outbreak area of *Chortoicetes*, although until then no direct evidence had been obtained, and at the western extremity of the Culgoa-Barwon outbreak area.

The first generation of the 1950-51 season may be expected to produce many more swarms of *Chortoicetes* in the New South Wales outbreak area. The present distribution of green feed has permitted a considerable dispersal of the large locust population in the outbreak areas. As soon as a relatively dry spell brings about a contraction in the area suitable for locust occupation, however, a great stimulus will be given to swarm formation, and mass emigration from the outbreak areas can be expected. The outlook, in fact, is for a major outbreak during 1950-51.

The experiments on the ecological control of *Chortoicetes,* which were commenced some years ago in the Trangie district of New South Wales, have been continued. These experiments are a natural outcome of the discovery, made in the course of earlier investigations, that swarms can be formed initially only in certain specific regions having well-defined soil and vegetational characteristics which favour locust multiplication. "Ecological" control would consist in changing certain of these characteristics in a direction unfavorable to the locust, thus reducing its rate of multiplication and delaying or preventing swarm formation and the occurrence of plagues. Two such changes, which seemed practicable and at the same time beneficial on other grounds, were chosen for testing. The first consisted in planting dense hedge-like barriers of suitable shrubs and trees between two types of habitat both of which have to be available to locusts if they are to realize their maximum potentialities for increase. For this purpose pairs of "outbreak centres" were selected and one member of each pair was subjected to the tree-barrier treatment, the other being left untreated. When the barriers are well established, the locust populations of the treated and untreated outbreak centres will be compared. The second change that has been attempted is to provide a pasture cover for the "scalds" and other sparsely-covered areas of compact soil that provide what has been termed the "oviposition habitat" of the locust, thus rendering such areas less acceptable to locusts for egg-laying.

It should be emphasized that the purpose of these experiments is merely to determine the potential value of the treatments for reducing locust multiplication, using small test areas. Although there is some reason to suppose that it would be practicable to apply such treatments on a large scale—particularly because of their value in other directions, such as pasture maintenance, prevention of erosion, and provision of station timber and drought-reserve fodder—the possibilities of large-scale application are not being considered at present. It would be quite wrong, therefore, to expect the experiments in progress to have any direct effect upon the development of plagues in the immediate future.

The ecological control experiments are necessarily of a long term nature, since the establishment of the tree-shrub barriers has to be awaited before any tests can be made of their value. Serious difficulties have been encountered in establishing trees on the soils occurring in the outbreak centres, and the only species that it has been possible to establish without excessive nursing in the early stages of growth is old-man saltbush, *Atriplex nummularia.* This species is now forming a tall, dense hedge in many parts of the treated areas, and it is hoped that in two or three years the barriers will have reached the stage where their efficacy can be tested.

Some preliminary work has been done on the identification of locusts and grasshoppers which have been damaging experimental crop-plantings at the Organization's field station in northern Australia, and which provide a serious threat to the success of agricultural development in that area.

Work on the taxonomy and phases of the Acridoidea has been continued. Manuscripts of the first two parts of a comprehensive revision of this group by James A. G. Rehn, of Philadelphia, are in the course of publication.

### 8. Cockchafers.

The larva of the pasture cockchafer, *Aphodius howitti* Hope, is an important pest of pastures in New South Wales and Victoria. It has already been shown that the pest can be controlled by the early application of DDT to the infested area, and that reinfestation of treated areas is very slow. Experiments are now in progress to determine the effectiveness of DDT applied in admixture with superphosphate, using conventional agricultural equipment.

With a view to devising a satisfactory method of controlling this pest, its distribution and ecology have been further studied. By means of field surveys and questionnaires completed by representative landholders, it has been possible to prepare a map of New South Wales and Victoria showing the distribution of *Aphodius* in these two States.

Observations on the behaviour of larvae in the field have indicated that larvae crawl over the surface of the pasture and occupy new areas while the soil surface is wet, emergence normally occurring just after dark. Between falls of rain, larvae are restricted in their foraging to vegetation within a very small radius of their burrows. The distribution of rainfall, therefore, significantly affects larval survival and the local distribution of feeding damage. The importance of migration in larval ecology is shown by the very high mortalities occurring when migration is prevented by means of natural or artificial barriers. The winter of 1949 was characterized by a well-distributed rainfall which enabled larvae to migrate frequently. Mortality was low, and the high initial populations were maintained through the winter. The damage caused to pastures, lawns, and golf links was not only very marked but persisted until the early spring.

Observations of adult behaviour already made have shown that adults pass through distinct feeding and oviposition phases, a different behaviour pattern being characteristic of each phase. Studies during the past year have supported this conclusion, though it now appears that adults may oviposit on two occasions, once in the soil at the point of emergence of the adult, and again elsewhere after feeding. There is ample evidence that adults may oviposit normally without prior flight or food. These conclusions account for certain previously inexplicable observations, for example, that infestation patterns tend to be repeated with remarkable accuracy from year to year.

The study of larval types and their correlation with adults has continued. When this work is completed it will be possible to identify most of the more important cockchafer larvae, and this will allow a much more exacting and ambitious study of the ecology of these species.

From time to time the adults of several native cockchafers cause extensive defoliation of eucalypts in New South Wales. At the request of the Forestry Commission of that State an investigation of this problem was initiated, and a study of the ecology of many of the species concerned has revealed many interesting facts. Severe defoliation occurred in the Canberra district during the summer, and species belonging to the following genera were involved:—*Anoplognathus, Liparetrus, Heteronyx, Automolus,* and *Anodontonyx*. *Anoplognathus* appears to be the chief offender in coastal areas and on the eastern part of the tablelands. *Liparetrus* gains dominance on the remainder of the tablelands, whereas *Heteronyx* is the most important genus on the western slopes and probably in other parts of inland New South Wales.

The life cycle of *Liparetrus* and *Heteronyx* has been worked out and observations on larval behaviour made. Whereas the larvae of *Liparetrus* probably occur throughout the pasture, those of *Heteronyx* are largely restricted to the soil beneath the canopy of Eucalyptus trees. Cockchafers belonging to these genera are usually considered to have a life cycle of twelve months' duration, but evidence obtained suggests the possibility that some of the smaller species may pass through two generations in this period. Little is known about the life cycle of *Anoplognathus* but it is possibly two years.

The facts that the major beetle defoliators have slightly different feeding habits, and that the peaks of their abundance do not coincide, greatly intensify the injury they cause. At Canberra, swarms of *Liparetrus* appeared in early spring and destroyed young growth on the trees attacked. Further swarms were recorded at intervals until mid-summer and these destroyed any new growth which followed the initial attack. Swarms of *Anoplognathus* occurred in mid-summer and in some instances completely denuded attractive host trees. At the end of February, the attack waned, but the new shoots which then appeared on *Eucalyptus blakelyi*, for example, were destroyed by a swarm of *Automolus*. Had the season been less favourable, it seems doubtful whether many of the more severely attacked trees would have recovered from this series of attacks.

Apart from the immediate loss caused by defoliating beetles in increasing tree mortality, their most important effect is upon the subsequent growth form of seedlings and saplings, probably reducing their ultimate value as shade or timber trees and certainly making the replacement of existing trees more difficult. All degrees of injury may be recognized. Some trees are only slightly attacked, but others are completely defoliated. It has been definitely established that some species of eucalypt are highly attractive to the beetles, others moderately so, and others not at all. The order of preference varies somewhat with the species of beetle. Apart from such inherent attractiveness, the most important factor determining the degree of damage occurring to a tree is the density of the surrounding timber stand. The wider the spacing of trees, the greater is the damage. The degree of damage is also influenced to a lesser extent by the aspect, the age of the tree, and its proximity to areas of suitable larval habitat.

### 9. Red-legged Earth Mite.

In view of the promise earlier shown by DDT in controlling the red-legged earth mite, which is a serious pest of subterranean clover in the winter rainfall areas of southern Australia, experiments were continued to devise an efficient method of applying this insecticide to infested pastures. Small-scale experiments demonstrated that concentrations of DDT as low as 0.5 per cent., applied in superphosphate at the rate of 1 cwt. per acre, gave almost complete control of earth mite for three seasons. Less effective control was obtained with treatments of DDT at lower concentrations.

The problem of applying DDT-fertilizer treatments to large areas by means of agricultural implements is still being examined. Superphosphate is usually applied to pastures by means of a "spinner" broadcasting implement, but when DDT mixed with fertilizer was applied by this method, the control of earth mite was rather disappointing. So far, the most effective agricultural implement for applying DDT-fertilizer mixtures to large areas has proved to be the drill. There are indications that as little as 90 lb. per acre of a DDT-superphosphate mixture containing 2 per cent. of the toxic ingredient will effectively control mites for two seasons when applied to the pasture with a drill. This may prove an economical control method, especially since it would not be necessary to treat the pasture annually.

As the earth mite is a pest chiefly of subterranean clover, it was expected that the yield of clover would increase appreciably if the earth mite were controlled. This happened in some experiments, but at times the clover yield actually decreased after DDT treatment. From preliminary investigation of this aspect of the problem, it appears that certain caterpillars usually feed on and seriously deplete the non-leguminous constituents of untreated pastures, thus enabling the subterranean clover to compete more successfully. DDT destroys not only the earth mites but also the caterpillars, with the result that the legumes suffer more vigorous competition from non-leguminous elements in the pasture. Treatment of pastures with DDT, however, results in greater total yields, and the mixed grass and clover pasture resulting from the treatment is for many reasons preferable to pastures too rich in subterranean clover.

### 10. Insects and Viruses.

Many economically important viruses of plants are transmitted by insects. The Division is undertaking research into several of the problems presented by these insect vectors; methods of control and fundamental problems of transmission are both included in the current programme. In recent years significant results have been obtained overseas in experiments on controlling certain insects by the distribution of insect pathogenic viruses. The Division is planning to undertake work in this important field.

(*a*) *Witches' Broom of Lucerne*.—The transmission of this disease from lucerne to tomato was effected by the common brown leafhopper *Orosius argentatus*. So far, transmission has not been accomplished from one lucerne plant to another. Attempts have also been made to transmit the disease by other jassids, including *Eurinoscopus punctatus* and species of *Euscelis* and *Thamnotettix*.

On the basis of information previously gained on the vectors of the disease, a spray trial was designed to determine the effectiveness of various concentrations of DDT against these and other insects attacking lucerne. In spite of unfavorable weather conditions, seed yields on plots receiving two sprays of 3 per cent. DDT at a rate of 4 gallons per acre were twice those of the controls.

(*b*) *Tobacco Yellow Dwarf.*—Further details of the transmission of this disease by the common brown leaf-hopper were studied and transmission was accomplished by all nymphal instars except the first. Work was commenced on the possibility of transmission by other species. Some difficulty has been experienced in maintaining colonies of these species.

(*c*) *Physiology of Virus Transmission.*—It is hoped to gain information on the mechanism by which insects transmit plant viruses. A study has been undertaken of the feeding of *Orosius argentatus,* using plants into which radioactive phosphorus had been incorporated. The isotope could generally be detected after five minutes' feeding, although there was considerable variation in uptake between individuals. This variation was insufficient to account for differences in ability to transmit the viruses of which this species is a vector.

The salivary glands of insect vectors of diseases are of special importance, because the pathogenic agent is usually injected into the host along with their secretions. The salivary glands of the cockroach are now being studied as a preliminary to the examination of these glands in more specialized insects.

### 11. TERMITES.

Damage to important structural timbers and other materials exposed to termite attack may be prevented by using either materials naturally resistant to termites, or susceptible materials treated with chemicals repellent or toxic to termites. The laboratory testing of timbers and other substances showing various degrees of resistance to termite attack, as well as materials treated with various chemicals, is a feature of the termite investigations. For this purpose standardized laboratory colonies of *Coptotermes lacteus* and *Nasutitermes exitiosus* are used. During the year 259 test colonies of *C. lacteus* and 261 of *N. exitiosus* were installed. Materials studied in these tests have included both native and overseas commercial timbers, treated plywoods, plastics, and anti-termitic materials.

Some of the more important test results were: (i) Tanalith impregnations as low as 0.06 per cent. (based on oven-dry weight of timber) gave almost complete protection against termite attack; (ii) the addition of 4 per cent. pentachlorphenol and 0.13 per cent. gamma-BHC to the glue line of plywoods did not produce a significant increase in termite resistance; and (iii) cellulose acetate butyrate plastic was found to be susceptible to termite attack, whereas polyvinyl chloride and polythene were unattacked under the test conditions.

Tests of the first group of commercial timbers were included with cross-checking experiments using *C. lacteus.* These tests placed the timbers in the same order of decreasing resistance to attack as did tests using *N. exitiosus,* viz.: *Tristania conferta, Eucalyptus acmenioides, E. microcorys, E. maculata, E. pilularis.* Testing has now begun on the second group of commercial timbers, which includes *Eucalyptus crebra, E. paniculata, E. micrantha, E. tereticornis, E. grandis,* and *Syncarpia laurifolia.*

The field testing of timbers and preservative treatments continues and a report on the condition of samples in the International Termite Exposure Test was prepared and forwarded to Madison, U.S.A.

The second annual examination of the soil-poisoning tests showed that both creosote and 5 per cent. pentachlorphenol (both used at the rate of 0.5 gal./ cu. ft. soil) have given complete protection for two years; 5 per cent. sodium pentachlorphenate and 10 per cent. sodium arsenate (both at 0.5 gal./cu. ft.) have both given complete protection for one year. The following additional tests have been installed: 5 per cent. DDT at 0.5 gal./cu. ft. soil, lead arsenate and white arsenic both at 4 oz./cu. ft. soil.

Approximately 500 series of termites have been received for identification during the past year. The bulk of these were collected during the Cooper's Creek expedition, October-December 1949. This material has added much valuable information to our knowledge of the distribution of many of the species occurring in eastern Australia. In addition, at least two new species and two previously undescribed castes were collected on this trip.

### 12. MISCELLANEOUS PESTS.

(*a*) *Orchard Pests.*—DDT spray has given a very high degree of protection against the codling moth in apple orchards during the three successive years in which it has been applied at about monthly intervals throughout the growing season. However, there is a tendency for growers to revert to the less effective lead arsenate because of the increased infestations of the mites (*Tetranychus telarius* and *Bryobia praetiosa*), the woolly aphid (*Eriosoma lanigerum*), and the light-brown apple moth (*Tortrix postvittana*), associated with the intensive use of DDT. Investigations on the control of these pests by chemical methods compatible with DDT codling moth spray programmes have been continued.

(i) *Mites.*—Experimental work with "Parathion" during the 1948-49 season showed it to be highly effective, in the form of a 0.01 per cent. emulsion spray, against all active stages of *T. telarius,* but owing to its lack of ovicidal action and of sufficient residual effects, and the high rate of natural increase of the mite, populations built up rapidly between applications. An attempt was made during the 1949-50 season to reduce mite infestations to negligible proportions by two applications of 0.02 per cent. spray with just sufficient interval between them to allow all eggs to hatch. At the time of the experiment the mite population consisted almost entirely of *B. praetiosa* and, although high mortalities were obtained, some active stages survived after each application. *B. praetiosa* thus appears to be more resistant than *T. telarius* to "Parathion". This failure of *T. telarius* infestations to develop was attributed to the activity of the beetle predator, *Stethorus vagans,* which almost exterminated the populations at the end of the preceding season. In another experiment, four applications of a 0.03 per cent. "Parathion" spray, prepared from a 15 per cent. wettable powder, prevented the development of mite infestations, whereas DDT-sprayed trees bore moderate infestations throughout the latter half of the season.

Observations on the predator *S. vagans* showed that the adults can tolerate prolonged contact with residues of DDT considerably in excess of those occurring on sprayed trees, and that DDT spraying of orchards has no obvious deleterious effect on the larval and adult stages, both of which are predaceous. "Parathion", on the other hand, is highly toxic to both larvae and adults.

The new acaricide di-(*p*-chlorophenyl) methyl carbinol, which has the added advantages of residual action against mites and of low toxicity to beneficial insects, is being examined following promising preliminary tests.

(ii) *Woolly aphid.*—Despite early emergence of the parasite *Aphelinus mali* in September and the provision of many unsprayed "nursery" trees throughout an orchard under observation, woolly aphids continued to increase in numbers and distribution during the season.

our applications of 0.03 per cent. "Parathion", as wettable powder spray, effectively reduced the initial festations and prevented further spread. Single plications of 0.01 per cent. "Parathion" as an nulsion spray were only moderately effective against eavy infestations, only aphids at the periphery of olonies being killed. Investigations on the use of etting agents to effect penetration of the white occulent covering to the colonies are progressing.

(*b*) *Meat Ant.*—One of the most troublesome pests ound homesteads and in the gardens of country towns the meat ant, *Iridomyrmex detectus* Sm. It is a very ommon species in the Canberra district, where experi-ents have been carried out with various insecticides control it. It has been shown that although all olonies are apparently eliminated from a given area by e use of insecticides, they may be re-established in ree ways: the treated area may be subsequently vaded by ants from colonies outside the area, colonies ay be established by females which fly into the area om beyond its borders, or workers which were absent om treated colonies during treatment may later return ad set up a new colony.

A nuptial flight of the meat ant was observed in arch, 1950, and the incipient colonies which resulted re being studied. Detailed observations on well-stablished colonies reveal that nests approximately feet in diameter contain about 45,000 workers, and olonies approximately 7 feet in diameter as many as 0,000 workers. The number of winged males and males showed considerable variation, but the larval opulation in most nests exceeded the total adult opulation. There is a positive correlation between e number of entrance holes and the total population f any mound, but the greatest depth to which galleries enetrate depends not upon the size of the colony, but pon soil type and the situation of the nest. The eepest galleries occurred between 3 ft. 6 in. and ft. 4 in. below the surface.

Collections of meat ants from a large part of Aus-alia were taken into consideration in drawing up a istribution map. It is evident that the species is ormally confined to areas having an annual rainfall bove 14 inches, but in drier areas may be found djacent to permanent water. Colonies of meat ants ave been recorded, for example, from the banks of ooper's Creek and the Paroo, Warrego, and Darling ivers. Away from the river bank it is replaced by dry-inland species, *I. viridiaeneus*.

(*c*) *Argentine Ant.*—At the request of the Aus-ralian Agricultural Council, the Division has com-enced an investigation of the Argentine ant, *Irido-yrmex humilis* Mayr., an introduced household pest lready of considerable importance in three of our apital cities. The standard Argentine ant bait, shown be most effective in controlling this insect elsewhere, as not been generally acceptable in this country ecause of the potential danger to humans of the odium arsenite used in its preparation. As the respon-ibility for enforcing a strict baiting programme has ot been accepted by appropriate authorities, it seems hat other control methods will have to be devised.

Preliminary tests with a dust containing 2 per cent. DT have shown that the application of the insecticide ant trails and nests will be a useful adjunct to ther control measures, but the more inaccessible olonies are not greatly affected by this treatment. he use of poison baits, in addition to DDT treatment, roved to be the most effective means of reducing ant opulation to a low level. Fumigation of colonies ith methyl bromide was found impracticable. ttempts are being made to develop baits at least s attractive as the standard sodium arsenite bait to he Argentine ant but much less toxic to humans.

(*d*) *Timber Borers.*—Work on the biology of *Lyctus brunneus* has been continued, with the major emphasis on the nutritional requirements of the larvae. A suitable basic diet has been prepared on which the larval development may be completed in two months. The effects on the mixture of removing components or altering their proportions are now being studied.

### 13. Taxonomy.

The accurate identification of insect species is of the utmost importance to the economic entomologist. Revision of several of the major insect groups represented in Australia is urgently required, and as opportunity arises this Division is encouraging specialists to undertake this work.

The taxonomic revision of the Australian ants is being continued by a specialist working in Melbourne on a grant from the Organization. The first two parts of a revision of the Australian locusts and grasshoppers by a United States authority are in the press and other parts will be published as they are completed.

Studies are in progress of the taxonomy of the beneficial Tachinid and Chalcid parasites which help to control natural populations of insects. The collections available for examination have been greatly augmented by specimens collected in the field and bred from various insect and plant hosts. The genus *Rutilia* of the family Tachinidae has received special notice recently, for it includes numerous large parasitic flies, some of which have now been bred from cockchafer larvae. As these flies are often very common, they doubtless assist in reducing cockchafer populations under field conditions. Caterpillars are more commonly the hosts of many of these fly and wasp parasites. A study of the Australian Tortricidae, a family containing several moth pests, is at present in progress. This will not only assist in the authentic identification of parasite hosts but will clarify several obscure points in the recognition of economic species.

Following the exceptionally favorable weather conditions which obtained in north-western New South Wales and south-western Queensland in 1949, officers of this Division conducted an extensive field survey of the insects of this area during October and November. Particular attention was given to the Cooper's Creek flood plain, a suspected outbreak area of the Australian plague locust, *Chortoicetes terminifera*. Valuable records of the occurrence of locust swarms and of the distribution of several other insect pests were made. The Australian sheep blowfly, *Lucilia cuprina*, for example, was shown to have an almost continuous distribution throughout the area traversed. Large collections were made of several economically important insect groups, the study of which will greatly improve our knowledge of the distribution and general ecology of the pest species.

Many identifications have been made for institutions and individual entomologists both in Australia and abroad. The collections in the Division's museum have been greatly increased by material collected during field surveys and also by valuable donations. Two notable insect collections were presented to the Division during the year, the extensive collection of Proetotrypoidea (Hymenoptera) of Mr. A. P. Dodd and the collection of Therevidae (Diptera) of Mr. J. Mann, both of Queensland.

## X. WILD LIFE.

### 1. General.

From time to time representations have been made to the Organization for work to be undertaken on the control of native or introduced mammals and birds which have become major pests of the agricultural and pastoral industry. Chief among these is the rabbit, which is estimated to do more than £30,000,000 damage each year, but dingoes, foxes, and emus are also of considerable significance.

Early in 1949, the Organization's Wild Life Survey Section was established to undertake a study of the life history, habits, and general ecology of these pests with the object of developing effective methods for their control. Initially the Section is giving all its attention to the rabbit. These investigations are discussed in detail in the next Section.

Allied to this work is the study of mutton birds which has for some years past formed part of the research programme of the Division of Fisheries. The progress of these investigations is described in Section 3 below.

### 2. Rabbit Investigations.

The investigation of the rabbit in Australia is the major—at present the sole—research project of the recently established Wild Life Survey Section. The programme of work comprises—

- (i) Basic ecological studies covering: reproduction and the factors determining the onset and cessation of breeding; movements and migrations; the effects of climate, vegetation, land usage, &c., on the population density; feeding habits and the qualitative and quantitative effect of rabbit grazing on pastures; and the effects of natural and artificial controls. The data obtained as a result of these investigations should point the way to improvements in the strategy and tactics of control, and should also permit the complex rabbit problem, with its varying regional aspects, to be defined in adequate perspective and detail. The inability to do this with the knowledge at present available is the chief stumbling block in the way of formulating the generally desired national policy for dealing with the rabbit problem.
- (ii) An investigation into poisons and poisoning.
- (iii) Further trials of the virus disease, *Myxomatosis cuniculi,* to determine whether it could be profitably employed as an agent of control in better-class country.

The myxomatosis trials have been given priority of attention, and are being carried out with the co-operation of the Division of Animal Health and Production (which was responsible for earlier extensive laboratory and field studies of the disease) and the Victorian and New South Wales State veterinary authorities. The first of the projected series of trials, at Gunbower, Victoria, has not reached a stage at which any conclusions can be drawn.

The initiation of the myxomatosis experiments coincided with the appointment of the greater part of the research staff of the Section. Before that (i.e. for most of the year under review) it was possible to do only preliminary work in the broad ecological field and on the problem of poisons. Laboratory assessments of the toxicity and acceptability of one or two poisons not hitherto employed for rabbit destruction were made. Sodium fluoracetate ("rat poison 1080"), as well as being much more toxic than strychnine, was found to be more acceptable and reliable in its effects, and field trials with this compound are now being begun. Attention is also being paid to unstable poisons which could be used to produce baits that would be dangerous for a period of one or two days only, or even one night; such baits might be of distinct value under certain conditions.

### 3. Mutton Birds.

The joint field investigations of the Tasmanian mutton bird (*Puffinus tenuirostris*) by the Division of Fisheries and the Tasmanian Fauna Board were continued. During field work in November at the Fisher Island research station, when the adult population on the island was banded, it was found that a large number of the breeding adults had returned to the burrows for the third successive season, but so far no young of known age coming in to breed have been observed.

Before the commercial birding season in 1950, over 1,500 young birds were banded on the five islands utilized for the mutton bird industry. However, owing to the phenomenally destructive floods at the egg-laying period, commercial operations on three of these islands were suspended this season.

On Babel Island 32 per cent. of the banded birds were taken during the season's commercial birding operations, which may be interpreted as meaning that this percentage of the annual crop of young birds was taken by the industry and 68 per cent. survived the operations. In 1949, 41 per cent. of the banded birds were taken and in 1948, 34 per cent. In Chapel Island the percentage taken was 21, compared with about 17 in previous years. In the three islands which were closed this year (Great Dog Island, Little Dog Island, and Little Green Island), the percentage taken has varied in the past from 50 to 70 and it may be that the drain on the young birds is too heavy for the stock to continue at unimpaired strength.

The mortality counts on Cronulla Beach were continued during the last quarter of 1949, and for the seventh successive year a relatively low mortality was found. Previous work has suggested that there is a correlation between the intensity of mutton bird mortalities and the abundance of southern bluefin tuna off the southern New South Wales coast. In poor bluefin years (such as 1941-42) there is a high mutton bird mortality. In December a yearling bird, banded as a fledgling at Great Dog Island in the previous March, was found among dead birds on the beach off Lake Conjola, 130 miles south of Sydney. This is the first occasion so far on which a marked bird has been found outside the Flinders Island area.

## XI. FISHERIES.

### 1. General.

Information that will facilitate the development of Australia's marine resources is being obtained by th Organization through its Division of Fisheries. Among the subjects under investigation are the location an extent of fishing grounds, the habits, including migra tion, of different varieties, fish populations, an methods of catching. Work on preserving and cannin fish is in progress in the Division of Food Preservatio and Transport (*see* Chapter XII., Section 6).

*Division of Fisheries.*—The work of this Division i outlined in the remainder of this Chapter.

The activities of the Division at sea have been carrie on by three research vessels operating full time o exploratory, oceanographical, and biological work The scientific work in connexion with the New Guine fisheries survey done by the Department of Externa Territories using M.V. *Fairwind* was in the charge o two research officers of the Division.

In April, 1950, the Indo-Pacific Fisheries Council, a the invitation of the Commonwealth Government, hel its second meeting at the head-quarters of the Divisio at Cronulla. Thirty-six delegates from ten countrie met to discuss the fisheries problems of the area.

To facilitate the work of the Division in Queenslan the Queensland Department of Harbours and Marin has built a marine biological station at Dunwich, Stra broke Island, in Moreton Bay. The living quarte were occupied in March, 1949, but the laboratory was not usable until November, 1949. The present staff of he station consists of one Research Officer, a Technical Assistant (field work on oysters and mullet), and an Assistant (hydrological analysis). The principal work f the station has been directed to an investigation of he spawning migration of mullet, the development of he oyster industry in Moreton Bay, an investigation of ome features of the sand crab industry, and the distribution of prawns.

The Division's work at the field station at Thursday Island has remained at a preliminary stage because the building of the laboratory and aquarium of the station has not yet been completed. During the year the building and furnishing of the living quarters were inished and the Queensland Government handed it over o officers of the Division.

The first number of the *Australian Journal of Marine and Freshwater Research,* which appeared in April, 1950, contained seven articles, all by officers of the Division.

### 2. Operations of Research Vessels.

During the first half of the year, the F.R.V. *Warreen* and the F.R.V. *Stanley Fowler* carried out a joint investigation of the tuna populations of the waters of northern Australia. The area allotted to the *Stanley Fowler* extended from Thursday Island westwards to 125° E. and northwards to 9° S. *Warreen* covered the area westward of 125° E. extending from North-west Cape almost to Timor and northwards to 9° S. During the latter part of this combined operation the M.V. *Fairwind,* which was also equipped for the capture of tuna, commenced work in New Guinea waters. Considerable attention was paid throughout her cruises to the observation of that fish. In this manner a considerable amount of data on the tuna species to be found in the vast area extending from the Solomon Islands in the east to Timor in the west has been obtained, but much work remains to be done on this material.

After completing the tuna survey, but before returning to her home port, *Stanley Fowler* spent several weeks at Thursday Island on work connected with the pearl shell investigations.

In addition to observations on tuna, attention was paid by both vessels to possible live bait species in the regions visited, and good evidence of ample supplies of suitable species along the north-west coast was forthcoming. *Warreen* also devoted some time to reef fishing and a small rich, unexploited ground was found inside Mermaid Reef. Other similar reefs northwards of this were visited and at some, numbers of native fishing craft from Timor and possibly elsewhere were encountered. It would appear that some of these reefs are recognized and long-exploited fishing grounds for such craft. Hauls made there were not so great as at those reefs where no native fishing craft were encountered.

*Warreen's* work in 1950 was planned to catch tuna in south-east Australian waters by the live bait method, using as a source of live bait the anchovies and pilchards supporting the small fishery in Port Phillip Bay. Bait was readily caught at the outset, but considerable difficulty was experienced in keeping it alive in the tank on board. Before this problem was overcome, the source of live bait failed, owing, no doubt, to the unusual conditions which killed a large portion of the fish population in Port Phillip Bay at that time. Endeavours to find a further source of live bait were fruitless, and *Warreen* then returned to Western Australia, where a large number of tow nettings were made in a search for larval and post-larval stages of the Australian salmon. During the year the Rottnest Island offshore traverse has been maintained.

In the latter part of the year, *Stanley Fowler* was employed along the New South Wales coast to obtain early stages in the life history of the flathead and spawning stages of mullet. Attention has also been paid to prawning grounds.

*Liawenee* continued to work in Tasmanian, Bass Strait, and Victorian waters almost solely on the biology of barracouta and school shark. This included the tagging and detailed examination of a large number of fish and the collection of associated plankton and hydrological data. Two hundred and forty-three adult school sharks were tagged and released, but none of them has to date been recaptured. Assessments made on the unfished stocks of school sharks in waters of the continental shelf have indicated that such sharks do not range much below the edge of the shelf, though a long line shot in 400 fathoms, believed to be the deepest shot yet made in Australian waters, took a good haul of fish. This shot was made where a school of fish was located near the bottom by the echo-sounder. Echometer records for the indications of the presence of sub-surface fish shoals were obtained systematically throughout the year. A hydrographical survey has been made of a previously uncharted bank at 40 fathoms off King Island. Results are to be forwarded to the appropriate authorities.

A lampara net lent to Australian Fishing Industries Ltd. was used by a fishing crew off Eden during the tuna season. In October, 8,352 lb. of tuna were taken in eight shots.

### 3. Fisheries Biology.

(*a*) *Trawl Fish.*—The work on the flathead of the trawl fishery of eastern Australia has been summarized in a paper, "The age composition of the New South Wales trawl flathead catch", prepared for publication by the late W. S. Fairbridge. The overfishing of flathead and the shifting of emphasis of the fishery to less valuable species are proved.

(*b*) *Australian Salmon.*—Continued work on the races of the Australian salmon (*Arripis trutta*) was summarized in a short paper presented to the Indo-Pacific Fisheries Council's second meeting. As a productive fishery for some salmon is being fostered in Western Australia, biological studies have been directed particularly to the salmon stocks of that State.

The relevant raciation data suggest that the South Australian and Western Australian salmon are identical. The respective fisheries of these States are thus being operated upon the same stock. In a previous working hypothesis it was considered that spawning takes place in the area of Cape Naturaliste on the western coast of Western Australia. Subsequent data make it apparent that spawning takes place over a much greater area, from the Cape Naturaliste area on the western coast to possibly east of Esperance on the southern coast. A denatant larval movement apparently occurs, the habitat of the juvenile forms extending from the area of Esperance to the western shore of Tasmania.

Tagging operations were carried out in the south-western area of Western Australia, three types of tags being used. An electrical narcotizing method was used in many cases to facilitate the attachment of the tags. Returns are extremely satisfactory, the majority indicating a contranatant pre-spawning movement.

Although a much more intensive fishery, in relation to the previous year, operated upon the salmon during this year, the total salmon catch showed a decrease of 500,000 lb. The customary criteria of overfishing are absent, the decrease being apparently due to variations in the normal movements of the salmon brought about by variation in the normal food cycle.

(*c*) *School Shark.*—A steady decline in the catch per unit of effort is still evident. Only by more intensive fishing in previously unexploited areas is the total landed catch being maintained at 3,000,000 lb.

annually. There are practically no undeveloped grounds now available to fishermen unless drastic alterations in gear and equipment are made to fish deep waters.

Both Victorian and Tasmanian authorities have realized the critical state of this fishery, and in an attempt to conserve stocks have introduced minimum size limits. This measure was designed to protect the juveniles during the particularly vulnerable inshore stage of their life history.

The seasonal migration of the juveniles during their first four years in inshore waters has been checked. During the winter months these sharks move into the deeper waters of the bays and sounds, but they return shorewards to the bays and estuaries in the late spring. There appears to be a differential size distribution in estuaries, the smallest sizes being found at the limits of the channels, the largest near the entrances.

Offshore, the migrations of the adults are being followed. Results to date indicate a late autumn movement of both sexes to the deeper waters of the continental shelf. During the winter period, copulation takes place. In the late spring, the inshore "spawning run" of gravid females occurs so that the young are born in the sheltered waters of bays and estuaries. Tasmania has declared such areas as sanctuaries for the juveniles. These regulations are based on the work of this Division.

Although 726 adult sharks have been tagged in offshore waters, only five have yet been recaptured. Four of these were caught within a 50-mile radius of the place of their release. The fifth travelled over 1,000 miles in nine months. So far, this is the longest recorded migration of any Australian fish.

(*d*) *Tuna.*—An extensive survey of tuna resources in northern Australia was made by *Warreen* and *Stanley Fowler*, the former vessel operating between North-west Cape and longitude 125° E. (York Sound) and working the adjoining parts of the Timor Sea. *Stanley Fowler* operated between Thursday Island, *Warreen's* easternmost point, and the contiguous portions of the Timor and Arafura Seas. Both vessels observed shoals of tuna, some of considerable extent, on many occasions. Most of the shoals seen were quiet, and it was thought that considerable catches could have been made with purse seines. Sea conditions for purse seining were ideal in the north-west sector of operations (up to 70 per cent. of the time was considered suitable) but less favourable between Arnhem Land and Thursday Island. The bulk of the tuna taken in the north comprised two species—northern bluefin (*Kishinoella tonggol*) and mackerel tuna (*Euthynnus alletteratus*) and were extremely small individuals; 35 per cent. of the former which were taken by the *Stanley Fowler* ranged between 1 and 2½ lb. weight and 39 per cent. between 7 and 13 lb. Only one large specimen was taken, a 23-lb. fish captured near Thursday Island.

Useful observations adding to the Division's knowledge of the distribution of the size groups of the northern bluefin were made. Of considerable biological interest were two specimens of juvenile tunas collected by *Stanley Fowler* near Peron Island in the Northern Territory; they were 4½ and 5 cm. in length. Other species taken were striped tuna (*Katsuwonus pelamis*), yellowfin tuna (*Neothunnus macropterus*), and dogtooth tuna (*Gymnosarda nuda*), the catches of the last-named representing a considerable extension of the range for the species, which hitherto had not been known to occur west of Torres Straits. The gear used by both vessels was restricted to trolling.

In southern Australia the southern bluefin tuna season was for the first time taken advantage of by commercial fishermen to any notable extent, and very considerable catches were made and processed.

(*e*) *Pilchards and Anchovies.*—Research on pilchards has been summarized in two papers which have been accepted for publication in the *Australian Journal of Marine and Freshwater Research.* Until a commercial fishery is developed in Australian waters, pilchard research will be discontinued. Although several important questions remain to be answered, the following conclusions have been established:—

(i) The season of spawning and surface shoaling is in the colder part of the year in New South Wales and southern Western Australia, and in the warmer part of the year in Victoria and South Australia.

(ii) The growth-rate is high in New South Wales, low in Victoria, intermediate in southern Western Australia, and in South Australia not clearly distinct (only scanty material available from the last two areas).

(iii) At least three main groups—eastern, south-eastern, and south-western—can therefore be recognized in Australian waters. The two former groups meet near the New South Wales-Victoria border, but the other boundaries are indefinite.

(iv) These main groups (races) contain subsidiary populations, some of which have been recognized from minor character differences and differences in natural fluctuations. In New South Wales there are two such populations which meet between Port Jackson and Jervis Bay.

(*f*) *Tasmanian Whitebait.*—As a result of evidence supplied by the Division on probable depletion of the northern population of whitebait in Tasmania, the Fisheries Department of that State closed the northern rivers to fishing for the whole of the season. The biological study of this species (*Lovettia sealii*) has been completed and a paper submitted for publication. The life history is similar to that of other anadromous salmonoids. Populations have been distinguished by characteristic growth rates and pigmentation, and also by abundance trends. It was found that vertebral counts merely indicated sexual differences.

(*g*) *Barracouta.*—Research on this plentiful and important fish has been greatly intensified. The object is to make a complete study of barracouta (*Thyrsites atun*) in the Bass Strait area. The area extends from Port Fairy in western Victoria to Eden in southern New South Wales, and south to the southern coast of Tasmania. In this study, attempts are being made to fertilize eggs and carry them to and beyond the larval stages. One fertilization experiment was successful, but the eggs did not reach hatching stage; the other experiments have failed.

In an endeavour to trace the life history of this fish, a programme of plankton tows, using an N.100 net, has been carried out from *Liawenee* at set stations in the Bass Strait area. Special efforts have also been made to obtain small fish from fishermen and anglers at all ports, in an attempt to get a gradation in size from the egg to the adult fish. The N.100 plankton samples have been obtained for twelve months. All eggs and larvae have been separated, and the programme is complete. An increasing number of small fish has been obtained and fishermen are co-operating. A special study is being made of stomach contents, and preserved samples have been collected.

In the study of maturity of barracouta, a revised description of each maturity stage has been compiled. It has been confirmed that the north-west Tasmanian coast barracouta "run" is at the spawning season, as it is everywhere else.

Age studies have been continued. Otoliths for this purpose are collected, numbered, and dated so that they can be related to the weight and length of the sh. In the past year otoliths have been collected rom 1,982 fish. Of 6,940 fish measured in the past ear, "length/weight ratio" has been worked out or 4,283.

Special efforts are being made to obtain samples nd measurements of the barracouta catch every month t Queenscliff, Victoria, and Triabunna, Tasmania. A measurer is also operating at Barwon Heads, Vicoria, as a check on the Queenscliff catch, and another measurer at the Ulverstone Cannery, Tasmania. The methods employed for heading barracouta in all the principal areas of the fishery have been studied and ccurately noted, as this information is important in elating the headless length to the total length of a fish.

The study of "milkiness" in barracouta has been ontinued, and the milkiness test is now carried out on a portion of each day's catch on board *Liawenee.* This condition is then related to the age and size of the fish.

Tagging has had first priority, with the object of establishing growth rate and migration. To date few tagged fish have been caught. All tags seen have probably been returned by fishermen. Cleaning methods in various areas have been noted for the sake of their bearing on tagging technique. The use of white Petersen tags has been discontinued and grey Petersen tags have been placed on 1,258 fish; small internal white body tags on 739 fish; plastic spirals on the caudal peduncle of 144 fish; and monel metal opercular strap tags on 99 fish. Thus the total number of tagged releases aboard *Liawenee* has been 2,230 fish. Posters giving details of types of tags used were circulated in all ports visited.

(*h*) *Mullet.*—Tagging of sea mullet in order to trace the movements of the fish was continued in Western Australia and in Queensland. Some support was given to the theory that the shoals of large mullet in the Shark Bay and Abrolhos Island areas are contributed to by the overflow of adult mullet from the south-western rivers by the capture of a mullet tagged in the Collie River and retaken at Geraldton sixteen months later, during which time it had grown seven inches. In Queensland waters, tagging has been confined to the Moreton Bay area. Prior to the spawning migration, movement within the bay took place in all directions from the tagging point. But during the migration season all movement was northwards. In the seven months since tagging commenced, there has been a 5 per cent. return of tags, which is considered very satisfactory.

(*i*) *Black Bream.*—A considerable amount of data has now been assembled on distribution of young and adult stages, larval and post-larval development, age determination, spawning habits, migrations, growth rate, gonad maturation, food, seasonal condition, and general ecology of the bream of New South Wales and Queensland. Tagging experiments begun in 1945 have been discontinued, as sufficient information for present requirements has been obtained. Over 7,000 fish have been tagged during a period of five years, using both gill clip and Petersen button tags. It is intended to concentrate now on intensive market examination, field sampling, and aquarium growth studies. More time is now being devoted to the study of other inshore species of equivalent economic importance, namely snapper, blackfish, whiting, tailer and garfish. Market measurements and scale collections have been continued throughout the year from Sydney and Brisbane.

(*j*) *Spanish Mackerel.*—Two species have received special study, the narrow-barred Spanish mackerel (*Cybium commersoni*) and the school mackerel (*C. queenslandicus*). Data have been collected on distribution, age determination, early development, spawning habits, migrations, growth, and gonad maturation. Much information has been obtained in tropical Australia and New Guinea during the current year. Further intensive field work by land and sea will be carried out this year in North Queensland.

(*k*) *Jack Mackerel.*—Hitherto known as scad, cowanyoung, or horse mackerel, the common name of *Trachurus novaezelandiae* has been changed to jack mackerel, to conform more with overseas common names and with a view to better marketing. Difficulties in handling and processing catches of this species have been largely overcome, and it is reported that two satisfactory canned packs have been produced. Biological work in the past year was mainly confined to making market measurements at Sydney and examining fish at Narooma during the spawning season. The successful tuna season caused a lack of interest in the jack mackerel, the New South Wales catch being only about 100,000 lb., compared with 270,000 lb. in 1947.

(*l*) *Freshwater Fisheries.*—(i) *Trout Investigations.*—Information obtained lends some support to the contention that there has been a falling off in the numbers of fish available to anglers in some of the rivers of Tasmania. The possibility of there having been some deterioration in the quality of the fish is being studied, and fish released in rivers and lakes have been marked with a view to following their movements and growth under natural conditions. Experimental work is being carried out on factors relating to the possibility of improving the stock by selecting fish for stripping.

(ii) *Indigenous Fish.*—Collections of native freshwater fish are being made in Tasmania with the object of discovering occurrence and distribution. Some species are good table fish and others may be of use as food for trout.

(iii) *Fish Culture.*—The effect of the enrichment of water by the addition of artificial fertilizers to enable a lake to support a greater quantity of fish life is being studied. The first enrichment does not appear to have yielded any striking results. It is expected that at the cold temperatures of the high altitude at which this experiment is being conducted, the increase in the abundance of food will not be very rapid.

### 4. Crustacea and Shellfish Investigation.

(*a*) *Crayfish.*—During the period of the crayfish investigations in Western Australia (1945-50), the catch there has increased from a total of about 700,000 lb. in 1945 with a home market value of about £40,000 to a total of about 6,500,000 lb. and an export value of about £750,000. The area fished is still expanding and increasing catches can be expected until the accumulated stock is fished to economic limits. It is likely that this will occur by the end of 1952 along the available coastline of about 300 miles from Port Gregory to Garden Island at depths to 30 fathoms. According to the present trends, it is possible for the annual catch from this area to rise to a maximum of about 10,000,000 lb. during this period. Analysis of the catch statistics and of crayfish length-frequency distributions in the Abrolhos, Geraldton, Lancelin Island, and Fremantle area fisheries indicate that, following the removal of the accumulated stock, an annual catch from the total area in excess of about 5,000,000 lb. would indicate a dangerous drawing upon reserves.

Careful management of the crayfisheries of the area is indicated. This should include, among other safeguards, full protection of females during the spawning season, the maintenance of an adequate minimum length, and the provision of suitable sanctuary areas.

Exploratory operations have been completed on the distribution of marine crayfish species in Western

Australian waters from Cape Riche in the south to Broome in the north-west. Five species are present. Of these, the Western Australian crayfish is the only one fished. Arrangements have been made for full-scale commercial and biological tests of the north-west crayfishes of the North-west Cape/Onslow area during the winter of 1950. Plans are in preparation for a similar investigation of the southern crayfish in the Albany area. It is hoped that the development of these areas will relieve the fishing pressure on the central crayfishing grounds.

The crayfishery for *Panulirus longipes* at the Abrolhos Islands continued, with an increased fishing effort during the 1949 season (71 men) and for the opening of the 1950 season (136 men). At the beginning of the 1949 season a tentative market estimate of 2,100,000 lb. of crayfish was made. The actual weight landed was 2,060,000 lb. An estimate of the April, 1950, landing of 700,000 lb. was made in March, 1950. The actual April landings were 660,000 lb. It was estimated further that by the end of June, 1949, and by the end of May, 1950, the majority of fishermen would have deserted the shallower grounds within the encircling reefs in favour of the outer, deep-water, nursery grounds. These events occurred as predicted. The successful predictions were based on the population surveys made in earlier years. The sequence of events suggests that a catch of 1,500,000 lb. should not be exceeded if the grounds of the Abrolhos area proper are to be maintained. It was apparent that the number of fishermen (71) operating in 1949 was slightly too high to allow the development of a carefully managed fishery, while the present number (136) prevents any rational exploitation of the stock accumulated during the closed season plus that accruing during the open season.

Surveys were made of the Lancelin Island grounds during the year. The fishery is still exploiting the accumulated stock, with a catch for the season of 3,500,000 lb. It is evident that this phase is ending, and it can be expected that within a short period the catch will be that of the yearly accruing stock, i.e., not more than 2,000,000 lb. yearly, provided the overall stock of breeding crayfish is not unduly reduced through an extension of the fishery northward.

Work has continued on the technical side of the industry and the problem of the balling up of the offal grinders which had hitherto prevented the effective treatment of some millions of pounds of crayfish heads as stock and poultry food was investigated and solved.

The 1949-50 plankton tow results at Port Arthur confirmed suspicions that 1948-49 was a poor year in that area for the survival of the phyllosoma larvae of crayfish. These larvae were quite plentiful in the 1946-47, 1947-48, and 1949-50 years but virtually absent in 1948-49. Meteorological records for 1948-49 did not show any conditions different from those expected for that time of the year. This work is continuing.

(*b*) *Sand Crabs.*—The Queensland Department of Harbours and Marine referred to the Division for advice on a claim by the crab fishermen that female crabs did not breed over a size of 6½ in. carapace breadth, and that consequently females of a greater size could be marketed without bad effects upon the industry. Investigation has revealed that in the three principal crabbing areas in Moreton Bay the proportion of males to females is: Scarborough 1.8 : 1; Woody Point 1.3 : 1; Cleveland 4.3 : 1. Thus males are everywhere more numerous than females in the catches, but considerably more numerous in the Cleveland area. The proportion taken of the male crabs which are of marketable size is: Scarborough, 68.8 per cent., Woody Point, 49.1 per cent., and Cleveland, 70.9 per cent. Thus the Cleveland crabbers obtain a much greater proportion of marketable crabs than do the fishermen of the northern part of Moreton Bay. Female crabs with fertile eggs have been taken over most of the year, and the largest female bearing fertile eggs has been 7.1 in. in carapace breadth. Thus the crabbers' claim has not been substantiated, and it is recommended that no change be made in the present law forbidding the marketing of female crabs of any size.

(*c*) *Oysters.*—Three small demonstration areas have been set up in Moreton Bay to show local oystermen methods of oyster cultivation. Several of the oystermen are developing the methods on a commercial scale under the guidance of the Division. Studies of growth of oysters under different conditions are continuing, as are studies on reproduction.

The Pacific oysters introduced into Tasmanian waters from Japan continue to flourish. Their growth rate has been very good, and spawning and a slight spat-fall occurred during last summer. However, the brood stock is not very large, and another importation of seed oysters is recommended in order to build the stocks up to a state where they can maintain and increase themselves.

(*d*) *Scallops.*—The predicted decline of Tasmanian scallops has continued, the catch of the 1950 season being considerably less than that of the previous year. The sampling work on this fishery is being continued.

(*e*) *Pearl Shell.*—Because the laboratory and aquarium provided by the Queensland Government are as yet incomplete, research has perforce been confined to field work.

Material has been collected from various parts of Australia for taxonomic studies on the genus *Pinctada*. Seven good species have been recognized, though the correct name to be used is not yet clear in all cases. The names in tentative use are—

*P. maxima*—Gold or silver-lip oyster.
*P. margaritifera*—Black-lip oyster.
*P. vulgaris*—Bastard oyster.
*P. sugillata*—Bastard oyster.
*P. carchariarum*—Shark Bay oyster.
*P.* sp. nov.—Groote Eyelandt oyster.
*P.* sp.—Moreton Bay.

The first four of these are to be found in the Torres Straits area. An attempt has been made to determine the spat setting periods and rate of growth of these species. Unfortunately, it appears that *P. maxima* and *P. margaritifera* do not "set" to any great extent in Thursday Island harbour. On the other hand, *P. vulgaris* and *P. sugillata* "set" well and are extremely common in the same locality. Consequently, work to date has dealt mainly with these species. It has been interrupted extensively by loss of gear, but this has now been replaced and the work is continuing.

Various types of spat collector have been tested but none of a really efficient design has yet been developed.

A small amount of rough survey work has been carried out in various parts of the Torres Straits and on the eastern coast of Cape York Peninsula. No new beds of *P. maxima* have been located but several heavily populated beds of *P. vulgaris* have been found.

## 5. OCEANOGRAPHY.

(*a*) *Oceanic Investigations.*—During 1949-50, further investigations of the dynamic and chemical properties of the deep waters off Rottnest Island, Western Australia, were continued. It is now evident that by comparison with east Australian waters, the current systems in this area are weakly developed and diffuse in the boundaries. This leads to the development of a shallower nutrient-rich upper layer, which undergoes greater nutrient depletion than do east Australian oceanic waters. Conversely, however, the deeper waters in south-west Australia contain greater utrient supplies. The annual range of surface tem- eratures at comparable latitudes appears to be less ı south-west than in east Australia.

(*b*) *Onshore Neritic Investigations.*—The elucida- on of onshore productivity cycles in south-east and uth-west Australia was continued during 1949-50. In south-east Australia there is evidence of a long- erm phosphate enrichment cycle from 1942 to the resent time. This has some correlation with the agnitude of onshore tuna stocks during the same eriod. A causal hypothesis based upon the effect f meteorological factors in the Tasman Sea, operating pon the east Australian current system, has been dduced. In south-west Australia the nutrient poverty f onshore waters has been confirmed again in 1949-50. Vhilst insufficient information is as yet available, no nnual cycle of chemical productivity such as is com- nonly found in temperate waters appears to occur n south-west Australian onshore waters.

A paper summarizing the conclusions to date of the ydrological work of the Division was prepared for he Indo-Pacific Fisheries Council's second meeting.

(*c*) *Estuarine Hydrology.*—A paper discussing the comparative features of the hydrology of Australian estuarine systems has been prepared for publication in the *Australian Journal of Marine and Freshwater Research.* A condensation of this paper was made for presentation at a symposium on the estuarine environment held during the second meeting of the Indo-Pacific Fisheries Council.

Regular field sampling in New South Wales, Victoria, Tasmania, and south-west Australia was continued in 1949-50, but greater emphasis will now be placed on the estuarine systems of northern New South Wales with their phosphate-rich waters and tremendous annual flood cycles.

A regular sampling programme in Moreton Bay and its tributaries has been commenced and, with the establishment of a regional hydrological laboratory at Dunwich, will be considerably increased.

In Victoria a statement of the hydrological changes occurring in Port Phillip since 1947 has been prepared for the Chief Inspector of Fisheries, who has been concerned at the recent heavy mortality of demersal fish stocks in the port. An explanation based upon persistently lower chlorinities and exceptionally calm weather conditions has been formulated. It is hoped to receive in 1950 regular water samples from the Victorian Fisheries Inspectors from a number of estuaries along the Victorian coast line.

(*d*) *Mud Metabolic and Enrichment Studies.*—In 1949 the sampling programme of bottom muds in the intertidal and marsh flats at Shell Point near Cronulla was continued. A water supply has now been connected to the laboratory at Shell Point, and it is hoped in 1950 to clear up a number of *ad hoc* problems in this work by the use of radio-active phosphorus. The practical application of this work is based upon the assumption that nutrients added to the mud surface become available to the plankton and oysters of this zone, with a minimum of loss by direct leaching to the overlying water. If this assumption can be proved by the use of radio-active phosphorus, an economic method for the control of oyster growth and for fish culturing in general becomes possible.

(*e*) *Oyster Ecology.*—At Pittwater, Tasmania, and Shell Point, New South Wales, regular water sampling has been conducted to provide information for the oyster biologists. Similar information will shortly be available in Moreton Bay. This work is designed to give information on the relationship between temperature, salinity, and meteorological factors and the spawning, growth rate, and other biological features of oysters. In Tasmania, a spawning of the Japanese oyster has apparently occurred in 1949, but the exact temperature will have to be more carefully defined in the coming season.

The collection of hydrological information for use in the fouling programme has been continued in 1949-50.

(*f*) *Freshwater Hydrology.*—In November, 1949, a fertilization of the bottom deposits of Lake Dobson, Tasmania, was carried out. Since that date, there does not appear to have been any marked increase in the nutrient content of the water, although the pH appears to be higher. The nutrient content of the bottom deposits is not much higher than it was before fertilization. It appears probable that the fertilizers added to the surface of the bottom deposits have sunk to subsurface level at which they are not accessible to surface biological utilization. If this can be confirmed in 1950, a new approach to enrichment of this lake will have to be attempted.

### 6. PLANKTON INVESTIGATIONS.

(*a*) *Western Australia.*—Analysis of plankton hauls in the Abrolhos and Rottnest Islands areas indicated that the area of occurrence of the Euphausiid, *Euphausia recurva,* lay from 20 to 30 miles further offshore in the summer of 1949-50 than in the summer of 1948-49. Combined with this was a tremendous increase in the area occupied by the Desmid, *Trichodesmium erythraeum,* and diatom species of the genus *Rhizosolenia.* The period of occurrence was lengthened (December to May instead of January to April). The coastal waters affected lay between Esperance and Shark Bay. It is noteworthy that the onshore salmon and sea herring runs were of smaller extent during this period.

(*b*) *Phytoplankton Research.*—Studies on the *Warreen* phytoplankton have been completed and two papers submitted for publication. These deal with the evidence of the phytoplankton on the movement of water masses in south-east Australia. West's diatom library has been purchased from London. It is the only diatom library in Australia and will be of great use to the universities as well as to the Division.

### 7. TAXONOMY.

The quantity of fish eggs and larvae now on hand is considerable, as collections from plankton nets and other gear date back to 1938. The largest recent collections are from tropical Australia and New Guinea. All material has now been examined, and individual larvae have been sorted into their respective families. Some detailed study of several families has already been made. To permit more complete identification of larval material, several important preliminary activities are in hand. The first involves the building up of a reference library of X-ray photographs of adult fish. This will enable use to be made of skeletal characters of adults for comparison with myomere counts, &c., or larvae. The second aid is the compilation of a comprehensive index to the Australian fish fauna. This is necessary because references are too scattered and numerous to be of practical use when used directly. A visible indexing method has been adopted and over 1,000 species have already been incorporated. The index is a compact and easily accessible reference, giving figure, description, references, and synonymy, together with a guide to distribution for each species. This is probably one of the first adaptations of visible indexing to systematic zoology.

### 8. MISCELLANEOUS.

(*a*) *Microbiology.*—Studies on diatoms on fouling plates and on oyster areas in Botany Bay have continued. These relate to fouling and also to the oyster programme.

A study of the bacteriology of oyster muds, the ocean waters, and fouling plates has been continued, and taxonomic work on fouling and shark spoilage has reached the stage of publication. Studies on bacterial adsorption and bacterial function in the oyster muds have begun. This work is designed as part of a study on the productivity of muds and the overlying water, and is of importance in estuarine fish culture.

(*b*) *Fouling by Marine Growths.*—The study of the fouling organisms of south-east Australia has been continued. Compared with previous years, the past year has been unusual as regards spatting times and relative abundance of fouling organisms. Stations have been extended to Moresby and Rabaul in New Guinea. A survey of *Watersipora cucullata* shows that this organism does not occur south of Cape Howe.

Tests are being made on methods of combating fouling in power-house conduits, which in Sydney alone costs about £5,000 annually for maintenance, and is a very appreciable contributor to Sydney's blackouts. No solution of this problem has been found in other countries as far as can be ascertained.

(*c*) *Algology.*—A survey of the *Macrocystis* beds of Tasmania and a study of the biology and rate of growth of this important seaweed have been commenced. The study of other seaweeds is to follow. Preliminary surveys show that at the present time at least 500,000 tons of *Macrocystis* are available, but it is not yet known how often this can be harvested. Samples of the weed were supplied to prospective users.

## XII. FOOD.

### 1. GENERAL.

The Organization's research on food processing, preservation, and transport is undertaken chiefly by its Division of Food Preservation with main laboratories at Homebush, New South Wales, and branch laboratories at Brisbane (meat investigations), West Gosford, New South Wales (citrus fruits), and Eden, New South Wales (fish). The work of this Division is described in Sections 2-12 of this Chapter. Work on the drying and processing of vine fruits is undertaken by the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria (*see* Section 13 below). Co-operative investigations on wines are housed in the Waite Agricultural Research Institute (Section 14).

Work on problems relating to the manufacture of dairy products is carried out by the Dairy Products Research Section at Fishermen's Bend, Victoria, and is described in Section 15 of this Chapter.

*Division of Food Preservation and Transport.*—Close co-operation with various outside organizations has helped to alleviate present shortages of staff and accommodation within the Division. In particular, the Division is indebted to the Botany Departments of the Universities of Sydney and Melbourne not only for accommodating four research workers but also for the opportunities afforded for close liaison on several aspects of research in plant physiology and mycology. The New South Wales Department of Agriculture also has co-operated in investigations on fresh fruit storage and on the canning and freezing preservation of fruits and vegetables; and is at present working with the Division in studies of the control of the Queensland fruit fly, undertaken at the request of the Department of Commerce and Agriculture. The more important part of the Division's work on the fruit fly will relate to the effects on the storage life of fruit of treatments by the "vapour-heat" process designed to kill larvae in infested fruit. A special room for these studies is being built at the Gosford laboratory.

Fish preservation investigations have recently been extended by the opening at Eden, a major fishing port on the southern New South Wales coast, of a small laboratory where chemical studies and canning preservation investigations are being conducted.

*Dairy Products Research Section.*—The capacity of the Section to deal with problems in dairy manufacture in Australia is at present restricted by lack of laboratory space. It is hoped that construction of new buildings at Highett will commence early in the coming year. In the meantime it has been possible to arrange for some of the work to be conducted in other laboratories.

The Officer in charge visited Europe and the United States of America last year, attending as Australian delegate the 12th International Dairy Congress held in Stockholm in August.

### 2. PHYSICS OF TRANSPORT AND PRESERVATION.

(*a*) *Cold Store Survey.*—Measurements were extended to two further types of store, an air-circulation store similar to some of the newer American types and a type designed to meet the special needs of fruit for canning. Analyses of these results and of data obtained earlier on other types are being made.

(*b*) *Rail Transport of Foodstuffs.*—(i) *Refrigerated.*—Further studies have been carried out in collaboration with the New South Wales Government Railways, the Queensland Railways, and the Queensland Department of Agriculture and Stock. The cargoes studied this year included packaged quick-frozen vegetables, frozen mutton and lamb, and mixed cargoes of fruit and vegetables which had been only partly precooled. Measurements of the thermal properties of one new type of refrigerated car were also made.

(ii) *Non-refrigerated.*—Calculations of the effects of size of stack, loading temperature, external temperature, and length of journey on the extent of self heating of peas and beans, which have relatively very high respiration rates, have been made, but it has not yet been possible to arrange a direct experimental check of them.

(*c*) *Evaluation of Canning Processes.*—The work referred to in last year's Report (p. 60) has been extended. It has been shown that the difference in consequences of the old and new definitions of an adequate heat process can be expressed quite simply in terms of an equivalent volume. This is much greater for products heating by convection than for those heating by conduction but it varies very little with normal variations in processing conditions.

(*d*) *Evaporation from Fruits.*—Analyses of the work done previously have shown the need for more exact data on the relation between the rate of evaporation and the drying potential of the storage atmosphere over the range of conditions encountered in practice (say 80-95 per cent. R.H.; −1° C. to +1° C.). Measurements designed to supply this information for pears are in progress.

(*e*) *Vapour Pressure Measurement.*—The behaviour of two purified proteins has been studied in the apparatus previously used for dried foodstuffs. A satisfactory technique for determining the end-point of a vapour pressure isotherm was worked out, and the results compared with published data.

(*f*) *Freezing of Egg Pulp.*—Measurements were made to obtain data needed in designing tunnels for freezing egg pulp. The heat transfer relations proved more complex than was expected, and a complete theoretical analysis is not yet possible. However, a formula which is believed to be accurate enough for practical purposes over the range of conditions likely to occur in existing tunnels has been worked out and published.

(*g*) *Freezer Burn on Edible Offals.*—The experiments reported last year have been continued, and the effect of water loss during chilling and freezing on the ncidence of freezer burn has been studied.

(*h*) *Colour Measurement.*—Data obtained on the spectral distribution of light from beef fat have been used in the preparation of a series of colour chips which are being tested as colour standards.

(*i*) *Temperature Measurement.*—A galvanometer amplifier to be used with a Micromax recorder, and an automatic selector for thermocouples, have been constructed for use in multipoint temperature recording.

### 3. FOOD CHEMISTRY.

(*a*) *Anaerobic Destruction of Ascorbic Acid (Vitamin C).*—Considerable attention has been given to the atmospheric oxidation of ascorbic acid in processed foods, but little to its anaerobic destruction. Since the oxygen content of many canned products becomes negligible soon after sealing, subsequent losses of ascorbic acid during storage appear to be predominantly anaerobic.

Until the end of 1949 all the investigations were carried out at 100° C., to obtain as much information as possible about the various factors before much longer studies were made at ordinary temperatures. The investigations at 100° C. have elucidated the effect of pH and have shown furfural and carbon dioxide to be products of the anaerobic destruction of ascorbic acid. Fructose, sucrose, fructose 1, 6-diphosphate, fructose 6-phosphate, and hydroxymethyl-furfural have been shown to accelerate the destruction. The fructose phosphates have a much greater effect than fructose itself.

Investigations on the anaerobic destruction at 30° C. have now been initiated. The effects of pH, fructose, and sucrose are being investigated and the production of furfural and carbon dioxide is also being studied.

The deterioration of solutions of oxalic acid (used in the determination of ascorbic acid) in the presence of light has been shown to be due to the development of peroxide. A note has been prepared for publication.

(*b*) *Natural Coating of Apples.*—The natural coating of apples affects the resistance of the skin to water loss and to gaseous diffusion; these in turn determine the internal atmosphere of the fruit, an important factor in its storage life.

Recent studies on Granny Smith apples have been mainly concerned with two fractions of the natural coating which have previously received little attention. These are the soluble-ester or oil fraction and the insoluble combined-acid or cutin fraction. The acids from the oil fraction have been separated into further fractions and subjected to preliminary analysis by distillation of the methyl esters. Increases in the oil fraction during storage of apples have been obtained over several years, and are being studied in more detail.

The insoluble combined-acid fraction has been found to change significantly only after a long period of storage. Attempts are being made to find out whether this fraction is present in the underlying flesh as well as in the skin. An improved technique for separating the skin has been developed.

(*c*) *Volatiles from Apples.*—A study of the organic volatiles produced by Granny Smith apples is being made, in view of the relation of volatiles to ripening, flavour, and superficial scald. Saturated fatty acids, both free and esterified, and saturated primary alcohols have been identified.

In identifying the acids and alcohols, it has been necessary to develop methods for converting them to hydroxamic acids and for separating the hydroxamic acids by paper chromatography. Difficulties in the chromatographic separation, such as the influence of metals in the paper, have been overcome.

The production of volatile esters by Granny Smith apples has been measured at 20° C., after various periods at 0° C. The rate of volatile ester production has been found to pass through a maximum at 20° C. The maximum appears after a somewhat variable period, but occurs later than the maximum production rate of the non-volatile esters of the skin. Measurements of volatile ester production in 6 per cent. oxygen are being made to find out whether the formation of alcohol is a limiting factor.

The effects of ethylene, ethanol, acetaldehyde, ethyl acetate, and ethyl butyrate on the development of superficial scald were tested in 1949, but none of these substances had any appreciable effect. The effect of free volatile acids, alkaline dips being used to remove the acids, is being tested this year.

(*d*) *Physical and Protein Chemistry.*—Investigations on protein denaturation—a major problem in freezing meat and fish—and on other aspects of protein chemistry have been initiated. Work is proceeding, in collaboration with the Fish Section, on the denaturation of fish muscle proteins during freezing. Methods have been developed for determining protein and non-protein nitrogen and sulphydryl groups. The biuret method has been adapted to the determination of protein nitrogen.

Investigations on the "renaturation" of silk fibroin, aimed at elucidating the fundamental mechanism of denaturation, are being made in collaboration with Professor H. S. Taylor and Dr. H. R. Tolley of Princeton University, United States of America. The effect of air during the dissolution of fibroin by cupriethylenediamine has been investigated. Satisfactory electrophoretic diagrams for soluble fibroin have been obtained. The infra-red absorption properties of soluble and insoluble fibroin respectively are being compared.

The stability constants of the complexes of metals with amino acids and dipeptides are also being studied, in collaboration with Dr. D. P. Mellor of the University of Sydney. A rapid polarographic method for the determination of these constants has been developed. This work should contribute to our knowledge of the structure of metal proteins and the mode of action of metal enzymes.

(*e*) *Chemical Changes in Dried and Frozen Foods During Storage.*—In a new series of studies, the chemical changes occurring in dried and frozen foods during storage are being investigated. The first stage of this work involves the development of techniques for separating and estimating the chemical components of the fresh foods and the breakdown products formed during processing and storage. This work is being combined with a study of factors affecting the darkening of dehydrated and sugared fruit. A series of storage experiments on sugared apricots, freestone peaches, and clingstone peaches is being made; the variables studied are the sulphur dioxide content, the ratio of reducing to non-reducing sugar, and the type of reducing sugar.

### 4. MICROBIOLOGY OF FOODS.

(*a*) Clostridium botulinum *Investigations.*—Studies of the temperature relations of this organism have been carried out with 20 strains available in this laboratory. Complete data are available for temperatures in the range of spore germination. There is evidence that the greatest variation occurs between strains at temperatures outside the range for spore germination. The work is being continued to check the validity of the results with vegetative inocula.

Studies of the water relation of this organism have been commenced using media of various water activities.

(*b*) *Heat Resistance and Germination of Bacterial Spores.*—Knowledge of the effects of heat on bacterial spores is essential in determining safe heat processes for canned food.

The investigation of the factors affecting the germination of heat-treated spores has been continued, some attention being given to the inhibitory substances, believed to be unsaturated fatty acids. Germination of heated *Bacillus* spores is inhibited by traces of unsaturated oleic, linoleic, and linolenic acids, and it has been found that the saturated fatty acids, myristic and lauric, are also inhibitory. This inhibition is counteracted by the presence of activated charcoal in the germination media. Some aspects of the work have been temporarily discontinued during the investigators' term of post-graduate study overseas.

Some experiments have been carried out on the germination of the spores of a species of a *Bacillus* in a chemically defined media. An unknown substance in yeast extract is required for germination although it is not needed for growth. This substance is not a vitamin or recognized growth factor.

(*c*) *Mould Growth Studies.*—The study of the water relations of a mould adapted to grow in a dry environment has been continued. Fairly detailed data have now been obtained in relation to growth on media of various water activities and at various pH levels. Some observations were made on the nature of the fruiting bodies which are produced by this fungus at low water activities.

(*d*) *Mould Wastage of Stored Fruit.*—A field experiment designed to determine the susceptibility of Statesman apples to infection by conidia of *Gloeosporium album* is being continued. Counts and measurements of size of lesions are being made at monthly intervals during the storage life of the fruit. Counts of open lenticels were made during the growth and maturation of the apples. These indicated a general increase in size and number of open lenticels during the season but there were large variations among individual fruit.

Some preliminary experiments have been carried out on the physiology of *Gloeosporium album* with respect to its germination and growth on synthetic media. Experiments on the organic-acid metabolism of the fungus and host have been continued, and ion-exchange resins are being used as aids to the analytical procedures involved in determining certain carboxylic acids by paper-partition chromatography.

(*e*) *Water Relations of Bacteriological Media.*—Experimental determinations of water vapour pressure isotherms of media have been made in the range of 0.99-0.90 water activity. The use of the thermoelectric method has been discontinued until more sensitive equipment is available.

(*f*) *Bacteriology of Liquid Eggs.*—The examination of 100 samples of liquid egg manufactured in New South Wales, for the presence of *Salmonella* organisms, has been completed.

### 5. MEAT.

(*a*) *Weight Losses.*—This work has been continued with pork sides only. Delay before freezing, the freezing rate, and the temperature of the freezer store are being considered.

(*b*) *Air-borne Contamination.*—These investigations are concerned with the techniques of "sterilizing" meat-holding spaces. The influence of the following factors on the rate of removal of viable organisms from the air are being studied: the levels of temperature; the relative humidity and rate of movement of the air; the nature of the contaminating organism; and the medium on which it is suspended.

During this work studies were made of the use of photoelectric determination of turbidity as a means of estimating numbers of bacteria in a suspension, and of the use of the Waring Blendor for disintegrating meat tissue for plate counts.

(*c*) *Investigations on Ozone.*—The relation between the ozone concentration in the equipment and the time and voltage supply to the ozone generator has been thoroughly studied, both with and without meat slices in the apparatus.

Improved equipment for spraying a definite number of organisms on the meat has been designed and constructed. It is being calibrated and the reproducibility is being determined.

(*d*) *Co-operative Frozen Beef Studies.* — These studies, which are being carried out in co-operation with the British Ministry of Food, the British Department of Scientific and Industrial Research, and the New Zealand Department of Scientific and Industrial Research, are aimed at finding out how animals should be treated before slaughtering, and how the meat should be handled and stored, if frozen beef is to be transported to England and distributed in the best possible condition—if possible, in a condition comparable to chilled beef.

The experiments have so far been confined to establishing techniques for evaluating the quality of the meat after treatment, and in particular to training a panel of tasters to evaluate the eating qualities of the meat when cooked. Two experimental shipments of frozen beef have been made to the British Ministry of Food, to supply material of known history for similar work in England.

(*e*) *Freezer Temperature Study.*—An experimental shipment of frozen beef was made in collaboration with the Refrigerated Cargo Research Council to obtain data on the influence of freezer temperatures lower than normal on the quality of material when shipped to England.

(*f*) *"Drip" Investigations.*—A study is being made of the exudation of liquid from the cut surfaces of frozen meat when thawed. The effect of size of sample and direction of cut are being studied as well as the rate and temperature of freezing and the conditions of thawing. The results are being correlated with the moisture and fat content of the meat and its acidity. The amount of "drip" is one of the criteria adopted in evaluating methods of freezing.

### 6. FISH.

(*a*) *Survey and Advisory Work.*—Advice has been given to numerous persons seeking information on the establishment of fish-processing facilities along the coastline in several States.

At the request of the Department of External Territories an officer of this Division has carried out a survey of fish processing methods used by the natives in Papua and New Guinea. The object of the survey is to determine the feasibility of improving existing practices, or of introducing new methods, to provide additional sources of protein for the inland population.

(*b*) *Fish Canning.*—Some preliminary work has been done on the canning of jack mackerel (*Trachurus novaezelandiae*), which has proved an inferior canning species when processed by existing commercial methods.

Experimental work has begun on some chemical aspects of the deterioration of canned fish.

(*c*) *Fish Freezing.*—Work on problems of fish freezing, which was suspended during the war, has been resumed.

### 7. EGGS.

(*a*) *Shell Coatings.*—Investigations on the effects of oil and other coatings applied to the shells before storage have been continued.

Many coatings have the effect of lowering the pH of the whites considerably. For instance, within a day or two of laying the pH of the whites of uncoated eggs will rise to, and remain in, the range of 9.0-9.2, whereas an oil coating applied soon after laying can maintain the pH in the range of 8.0-8.3 for long storage periods. Studies have been made of the free and combined carbon dioxide in the white of coated eggs, with the view that the observed pH values might be accounted for by restriction of carbon dioxide loss through the shell. There are, however, significant discrepancies which prevent these differences in pH being explained solely by changes in free and combined carbon dioxide. The effects of oiling on the quality of stored eggs have been further investigated in several small- and large-scale experiments. The criteria used in assessing quality were candling grade, albumen index, percentage of thick white, yolk index, flavour of boiled eggs, and moisture losses. The results obtained have confirmed findings mentioned in the last Annual Report, viz., that when stored at room and low (1° C.) temperatures, oiled and unoiled eggs show no important differences in quality except for a marked reduction in loss of weight and, occasionally, a slightly better flavour in the oiled eggs. Several American investigators have claimed that oiling greatly retards the normal decline in quality during storage; this has not been confirmed, but the cost of oiling eggs for export may, perhaps, still be justified by the reduced weight loss and the consequently smaller air cells.

The merits of a proprietary substance, " Plast-o-trete ", as a coating material have also been investigated. After both three and six months' storage at 1° C., there were no significant differences between these coated eggs and oiled and unoiled eggs except in weight loss. The rates of loss were slightly higher in the " Plast-o-trete " than in the oiled eggs.

(*b*) *Breakdown of Thick White*.—In the new-laid egg, the thick white is a firm jelly-like material constituting about two-thirds of the total volume of the white. During storage there is a steady reduction in firmness and volume. As a preliminary to studying the nature of this breakdown, the rheological properties of thick white at various times during storage are being investigated in some detail.

### 8. FRESH FRUIT AND VEGETABLE STORAGE AND TRANSPORT—PLANT PHYSIOLOGY AND BIOCHEMISTRY.

Any research programme on the storage of fruits and vegetables—which is essentially an attempt to preserve living excised plant parts for as long as possible in a healthy condition—must necessarily be largely directed towards obtaining a fuller understanding of their physiology and biochemistry. The Section has engaged in studies on the metabolism of the living cell, particularly the synthesis and breakdown of the protein constituents; and on the mechanism of respiration, the main means whereby the plant derives its energy. Certain plant tissues, such as apple tissue and carrot root tissue, are especially suited for experiment, and much work has been done on these.

(*a*) *Salt Absorption and Accumulation*.—During the year, the early stages of absorption of salt by carrot tissue have been studied in great detail and evidence has been obtained that the salt can penetrate some distance into plant protoplasm, indicating the absence of a surface membrane resistant to entry of salt. Subsequently, the salt enters only slowly by the accumulation mechanism and it has been shown that this mechanism, which depends on respiration, can be inhibited by the substance 2, 4-dinitrophenol, which does not inhibit the respiration at the same time. This limitation of accumulation does not appear to be due to an increase in the permeability of a membrane to allow leakage of the salt which has been accumulated. This observation has an important bearing on the problem of how the energy is transferred from respiration to bring about the accumulation of salt. Dinitrophenol is believed to interrupt the transfer of energy by the phosphate transfer system. A short paper incorporating some of these observations has been prepared for the discussion on this subject at the International Botanical Congress in Stockholm in July, 1950. Two review articles on this work have been prepared during the year.

The study of respiration in plant tissue, and that of accumulation of salt, are linked by current work on the enzyme cytochrome oxidase. Further work on this enzyme, in collaboration with Mr. D. Weeks of the Botany School, University of Melbourne, has shown that it is undoubtedy concerned in the increase in respiration which occurs when salt comes into contact with the surfaces of plant cells, and also in the accumulation mechanism. A paper on this work has been submitted for publication.

One of the problems in plant respiration specifically associated with the ripening of fruits is the sudden rise in respiration rate—the climacteric rise—at or about the time of ripening. A new hypothesis as to the cause of this rise in respiration, which has never been satisfactorily explained, is being tested. Both apple tissue and banana tissue are being examined, in an attempt to link the rise in respiration rate with a hitherto unexplored chemical change in fruit tissue.

(*b*) *Nitrogen Metabolism in Apples*.—Earlier studies on apples in storage had confirmed English observations indicating that protein synthesis continued after the fruit was removed from the tree. The protein is formed from the soluble nitrogenous compounds present in the fruit at time of picking, and this synthesis probably has an important bearing on the storage life of the fruit. A study of this process has been continued with fruit kept at three different temperatures. It is a tribute to the work of the Section that the officer concerned with nitrogen metabolism has been invited to contribute a chapter on the structure and synthesis of protoplasm to a book being prepared by the American Society of Plant Physiologists.

(*c*) *Apple Growth Experiments*.—The development of apples on the tree has a profound effect upon their subsequent behaviour. This is best illustrated by the work of Carne and Martin in Tasmania; these workers showed conclusively that not only do small fruits keep better than large fruits, but fruits of a given size from a heavy crop keep better than fruits of the same size from a light crop, indicating some difference in the physiology of the fruits. To elucidate this size effect, an investigation was begun in the 1947-48 season. Samples of fruit were taken from the trees at regular intervals from blossoming to full maturity; these samples were analysed for fruit size, cell size, cell number, protein and total nitrogen, carbohydrates, organic acids, and respiration rates. Two draft papers have now been prepared, one dealing with the anatomical changes and the other with the chemical changes accompanying the development of the fruit, and some important observations on the significance of size have been recorded. These studies have paved the way for some collaborative work with the Division of Plant Industry on the effect of crop size on the anatomical and chemical differences between fruit.

### 9. FRESH FRUIT STORAGE AND TRANSPORT TECHNOLOGY.

A number of storage and transport problems have been investigated during the year; some are comparatively short-range projects, others have been in progress for several years.

(*a*) *Skin Coatings for Fruits.*—During the years 1940-46, the Section largely concentrated on the question of prolonging the storage life of fruits, particularly apples, by the use of wax or oil substances applied as a thin layer to the skin. Three papers have now been written in preliminary draft, dealing with the physiological effects of skin coatings, with coatings in cool storage, and with coatings in common storage; they include much information not only on conditions under which coating is beneficial, but also on the limitations of the method.

(*b*) *Orchard Variability Experiment with Apples.*—An experiment on variability in the storage behaviour of apples has been continued. Apples of the varieties Delicious and Granny Smith from two orchards in the Orange district, New South Wales, have now been placed in cool store for a standard time under standard conditions in five successive seasons, the fruit being subsequently examined for storage disorders. Comparisons of fruit of different sizes within trees, between trees, between orchards, and between seasons are now possible. Considerable differences in keeping quality have been established, and the experiment will conclude after the examination of the 1949-50 season's fruit.

(*c*) *Maturity and Storage Studies with Apples.*—Several years ago American workers suggested that a constant number of days after full blossom might be adopted as a criterion of maturity in apples for picking purposes. To check the validity of this criterion, fruits of the two varieties Delicious and Granny Smith from the Orange district have been examined over several seasons. Samples were picked after varying times from full blossom, placed in store under standard conditions, and examined for quality after a standard storage period.

(*d*) *Cool Storage of Peaches and Nectarines.*—Work on the storage of peaches and nectarines has been carried out over a number of years, with a view particularly to finding out the best temperatures for storage and ripening, the permissible length of storage to obtain satisfactory ripening, the effects of delay before storage, and the effects of gas storage. Work on nectarines and two varieties of peaches, Hale and Elberta, has been completed. The importance of rotting, particularly by the brown rot fungus, has again been shown to be a serious limiting factor in storage life. This season the storage qualities of some new varieties grown on the Bathurst Experiment Farm, New South Wales, have been examined.

(*e*) *Storage of Lemons.*—Work on lemon storage has been continued at the Citrus Processing Research Laboratory at Gosford, New South Wales, using the ordinary method of shed storage. The importance of tree vigour in relation to good keeping quality of lemons has been established, and the relation of good keeping quality to maturity has been defined. These experiments are being repeated in the current season, and fruit is also being stored after a carefully planned spraying treatment, in an attempt to reduce stem-end rot. The effect on keeping quality of the artificial growth substance, 2,4-dichlorophenoxyacetic acid, is also being investigated.

(*f*) *Storage of Oranges.*—Experiments are in progress at the Gosford laboratory to determine the variability in mould wastage in oranges, and to find out how far this wastage can be controlled by experimental processing, as compared with ordinary commercial methods of handling. Marked variation between fruit from different orchards was demonstrated for both Valencia and Washington Navel oranges.

(*g*) *Storage of Pears.*—It has always been believed that delay after picking pears lowers their keeping quality, but the delay permissible in practice has not been well defined. Two varieties from orchards in the Orange district are being examined after storage with varying periods of delay. In addition, the investigation of the safe limits of carbon dioxide in gas storage of Winter Cole pears has been re-opened, following recent serious outbreaks of the brown heart disorder in commercial stores at carbon dioxide concentrations previously considered safe for this variety.

(*h*) *Brown Rot.*—Brown rot in peaches and apricots has frequently caused serious loss, especially in wet seasons, when these fruits are stored for subsequent processing, e.g. in canning factories. While the full control of this disease is basically a field problem and outside the activities of this Division, some experiments are being carried out in collaboration with plant pathologists of the New South Wales Department of Agriculture. The aim of these experiments is to determine how far modified methods of handling, aimed at reducing the temperature of the fruit as rapidly as possible after picking, will minimize losses due to both *Rhizopus* (soft rot) and *Sclerotinia* (brown rot). A study of the effect of temperature on the growth rates of both organisms in the fruit has been carried out.

(*i*) *Transport of Peas and Beans.*—Problems in transporting peas and beans have been investigated in collaboration with the Physics Section: these crops, being fast-respiring products, generate much heat after picking and frequently overheat during transit, with consequent losses. The respiration rates of peas and beans have been measured at different temperatures, and at different times from picking, in order to obtain heat production data for design purposes.

(*j*) *Queensland Fruit Fly.*—A new study of great importance is on methods of sterilizing fruit infested by the Queensland fruit fly. Two methods appear likely to be satisfactory and can be used with different varieties of fruit; one is a vapour-heat treatment for some hours, and the other a low-temperature treatment for some days. Both will be investigated in collaboration with entomologists of the New South Wales Department of Agriculture and of the University of Sydney. A large population of flies is being bred under controlled conditions for use in this project.

### 10. Canning and Fruit Products.

(*a*) *Vegetable Canning.*—Extensive studies of canning peas were made at Batlow, Millthorpe, and Blayney in New South Wales and at Devonport, Tasmania. At all four centres data relating maturometer readings to alcohol-insoluble solids values were obtained.

Storage experiments with shelled peas at Devonport indicated that peas held overnight at atmospheric temperature and in cold store were inferior, when canned, to those processed without delay. Cold-stored peas in the advanced maturity range were superior to those held at air temperature, but no difference was observed between less mature peas. Tasting tests on canned peas over a wide range of maturity indicated preference for those having alcohol-insoluble solids values from 11 to 15 per cent.

Six varieties of canning peas were grown in a replicated trial at Millthorpe, but the value of the work was impaired by heavy rain during the maturation period. Tasting tests of the canned varieties and an analysis of yield data are proceeding. A method of field sampling for the assessment of maturity, rate of maturation, and yield was tested in a replicated trial at Blayney and found to be satisfactory. The method will be used in the 1950-51 series of variety trials.

The tissue-firming investigations begun in 1948 were continued, and a programme designed to define the optimal time, temperature, and salt concentration relationships was completed. Some progress has been made with a fundamental study of the phenomenon, and there are indications that pectic constituents may be involved.

Analysis of carrot data showed that Oxheart variety was unsuitable for canning as "baby carrots". The total yield doubled in seventeen days, but the proportion of "baby carrots" decreased from 75 per cent. to less than 5 per cent. Red-cored Chantenay was found to be considerably better in this respect.

No difference in fibre development was observed in green and white asparagus held for several hours as compared with similar material canned without delay. Fiberometer measurements of green and white spears held for three days at room temperature and a 32° F. were significantly increased, both lots showing approximately the same value. Bitterness was found to occur in asparagus tested immediately after canning. It was absent after one month's storage at room temperature, the rate of disappearance being greatest during the first week in store. The bitter principle occurred in highest concentration in the butt of the spear and decreased towards the tip end.

(*b*) *Fruit Canning.*—Varietal trials of freestone peaches for canning were continued in the 1950 season, using fruit grown at the Bathurst Experiment Farm of the New South Wales Department of Agriculture. Canning facilities provided by Gordon Edgell and Sons Limited, of Bathurst, enabled the fruit to be canned in the shortest possible time after picking. In the 1949 trials, three varieties—Blackburn, Elberta Late, and Elberta Cling—were classed as "outstanding", and six varieties—J. H. Hale, Elberta Dripstone, Success, Viceroy, Grays, and Fragar—as "satisfactory". These varieties, with the addition of Halehaven, were included in the 1950 trials. The assessment of quality in the test packs is not yet completed, but scores obtained so far indicate that Success will be the outstanding variety for 1950.

Investigations on the canning of bananas have shown that packs acceptable in flavour, texture, and appearance can be produced. Attention has been concentrated on a discoloration problem which caused considerable losses in commercial canned bananas. The discoloration appears to result from oxidation of tannins in the bananas, and can be prevented by a suitable heat process.

Varietal and processing trials on canned rockmelon were continued, and it was again demonstrated that the canned product, either as pieces or puree, was very acceptable, particularly in combination with passionfruit.

(*c*) *Fruit Juices.*—The first pick of Valencia oranges was taken from the Kulnura experiment, which was designed to determine the effect of Bordeaux sprays on juice bitterness. Canned juice from this fruit showed no bitterness after any of the spray treatments, a result which is in line with previous experience that copper sprays do not induce bitterness in fruit from young trees.

Continuous progress is being made in the elucidation of the structure of limonin, the bitter principle in orange juice. Attack on classical lines by oxidation and hydrogenation has yielded a number of crystalline derivatives, and spectroscopic studies in the ultra-violet and infra-red regions have provided useful supplementary evidence of the presence of ketone and lactone groups.

The investigation on the effect of oxygen on deterioration of flavour and loss of ascorbic acid in canned orange juice has reached a stage where some of the results are being prepared for publication. It was found that loss of ascorbic acid occurred in two stages —a short period of rapid loss while oxygen remained in the can, and a period of much slower loss in subsequent storage. The mechanism of the effect of free oxygen on the rate of loss of ascorbic acid is at present obscure.

(*d*) *Container Investigations.*—The suitability of electrolytic tinplate for packing Australian canned foods is being studied at the request of the Department of Supply. A series of test packs of peaches, pears, sweet corn, and tomato juice has been prepared and stored at 100° F. for examination at regular intervals. Investigations on can lacquers are directed chiefly towards developing improved test methods, particularly reliable accelerated tests of lacquer performance. One important problem which is receiving attention is the search for a satisfactory internal lacquer for the caps for glass packs of highly acid foods containing preservatives. Commercial tests of a sulphur-resisting lacquer of satisfactory laboratory performance were completed.

(*e*) *Equipment.* — Investigations have begun on commercial techniques for sterilizing vegetables before can filling and closing. The pre-can sterilization equipment consists of a modified steam-pressure blancher joined to an adjacent can closer by means of a steam tunnel.

A continuous method of recording temperature change in cans processed by thermorotation has been developed, and will be used in investigating the performance of the thermorotary machine.

### 11. DEHYDRATED FOODS.

(*a*) *Vegetables.*—Further investigations on onion varieties, in collaboration with officers of the Victorian Department of Agriculture, have confirmed the necessity for a breeding programme designed to produce a variety possessing the special characteristics required for dehydration. This would require the agronomic and chemical characteristics of selected bulbs to be assessed without interfering with their use for seed production in the following season. This is not possible with the usual methods of chemical analysis, and accordingly attempts are being made to find a suitable simple physical measurement which is highly correlated to the desired chemical composition and can be readily made in the field.

In collaboration with other Sections of this Division, a preliminary examination of the relative acceptability of canned, frozen, and dehydrated peas has been made.

(*b*) *Fruit.*—Previous experiments with glacé fruit indicated that the added sugar gave an extended storage life as compared with normally dehydrated fruit. Further experiments to substantiate this are in progress. Investigations on the preparation of glacé apricots, freestone peaches, and clingstone peaches have been continued. The variables studied included fruit maturity, temperature of the syrup used for steeping, method of sulphuring, blanching time, and the use of glucose in place of invert sugar in the syrup. Present results suggest that apricots and freestone peaches yield a better glacé product than clingstone peaches, chiefly with regard to texture and flavour.

One disadvantage of glacé fruit is the sticky surface associated with the relatively high moisture content. Attempts have been made to find a suitable film-type coating to eliminate this defect. Of several materials tested the most promising was low-ester pectin.

Some attention has been given to the preparation of crystallized pineapple, and the results show that a satisfactory product may be obtained with single-stage steeping in syrup in place of the multistage steeping commonly used commercially. The chief factors involved in the quality of the final product were maturity and time of blanching.

Further experiments on banana dehydration related to the form of subdivision, blanching time, level of sulphur dioxide, and temperature of drying. The chief defects of the dried output are a "cooked" flavour and a tendency to be astringent.

One difficulty in the experimental dehydration of fruit is to obtain a predetermined level of sulphur dioxide in the dried product. A detailed study of the factors influencing the uptake of sulphur dioxide by dried fruit has been undertaken, and the necessary equipment is being procured.

Laboratory analyses have shown that β-carotene is highly stable in dried apricot. This is contrary to its behaviour in other foodstuffs, where loss occurs at a rate depending on the storage atmosphere, time, and temperature. To provide more detailed data on this finding, a further experiment is in progress.

(*c*) *Meat*.—Investigations on the processing of dried meat have shown that the age of the sheep has little direct effect on the quality. As in previous experiments on this problem, the effect of seasonal reduction in the quality of pastures has not been eliminated.

Using the most satisfactory method of processing, samples of dried meat were prepared and submitted to the Army, Air Force, and British Ministry of Food for test, and favorable reports have been received from all three sources.

Compression of dried meat resulted in improved keeping quality. The compressed packs have the advantage over gas packs that they occupy approximately 50 per cent. less space, but the texture is damaged to an extent determined by a number of variables, which are now being examined in detail.

Equipment is being installed for investigations on the dehydration of meat in forms other than mince. Other equipment installed will be used for obtaining physical data on drying.

### 12. Frozen Fruits and Vegetables.

Experiments on the preparation, processing, freezing, and storage of some fruits and vegetables were recently begun in the Division's Homebush laboratory. These investigations are being conducted jointly with the New South Wales Department of Agriculture, one of whose officers is in charge of the work.

The investigations so far have been concerned mainly with defining suitable varieties for freezing preservation, and with methods of preparation, particular attention being given to peas and freestone peaches. Much time has been spent also on developing experimental techniques.

### 13. Dried Vine Fruit.

Investigations on sultana drying have been continued at the Commonwealth Research Station, Merbein. Further work on oil emulsions for use in the cold process has shown that certain sulphonated fatty acid esters, such as sulphonated butyl oleate, are better than vegetable oil emulsions for this purpose. There is, however, evidence to suggest that the conditions under which sulphonation is carried out have a marked effect on the efficiency of the resulting product.

The effect of treating sultanas with sulphur dioxide prior to dipping by the cold dip process has been investigated. It has been shown that it is possible to remove "green tinge" in this manner, but that the amount of sulphur dioxide required depends on the degree of maturity of the fruit, the temperature, and the degree of exposure to light; and that the method is therefore difficult to control. An initial sulphur dioxide concentration of 50 to 80 p.p.m. gave best results in most cases.

Sulphuring in this way gave some measure of control against mould growth on the drying racks during unfavorable weather, but concentrations of the order of 200 to 300 p.p.m. were required to prevent damaged berries from fermenting under similar conditions. Sulphuring of sultanas in commercial lots with the fumes of burning sulphur before dipping, or while drying on the racks, reduced the damage due to mould attack and fermentation during the exceptionally unfavorable weather experienced last season.

Investigations also showed that when fungicides such as potassium propionate or sodium phenyl phenate were incorporated in the dip mixture, a useful measure of protection against spoilage of the fruit during drying was obtained. However, experience during the past sixteen years has shown that sun-drying methods are inadequate during unfavorable seasons, and that a system of supplementary dehydration is necessary on each vineyard, to permit continuous drying and the satisfactory handling of the crop during periods of wet and humid weather.

Further work on the bulk hot-dipping of sultanas has shown that with suitable equipment the bulk handling methods at present in general use with the cold dip process can also be used with hot dip mixtures similar to the Johnson or the mixed dips.

Excellent results were obtained by sulphuring sultanas for ten-fifteen minutes prior to bulk hot-dipping. Sulphuring greatly reduced browning, permitting the use of longer periods of immersion and of higher temperatures. In this way it was found possible to obtain both a very fast drying rate and a light-coloured product, while green tinge was completely eliminated.

Packing problems have arisen as a result of the damaged condition of the fruit this season. Modified packing procedures have been devised for lexias to permit the product to be satisfactorily seeded, and special casein-paraffin oil emulsions have been produced for use in salvaging broken and sticky fruit. Work is also being carried out on an improved fruit washing machine, in co-operation with the Mildura Co-operative Fruit Co. Ltd.

### 14. Wine.

The investigations directed by the Committee on Oenological Research comprising representatives of the Organization, the Federal Viticultural Council, the Australian Wine Board, and the University of Adelaide, have continued at the Waite Agricultural Research Institute.

(*a*) *Sherry Investigations*.—The study of the influence of various factors on the growth and metabolism of the film-forming yeast (*Saccharomyces beticus*) known as sherry flor has continued during the year. The environmental conditions and the type of wine required for satisfactory flor growth can now be defined, and many of the factors which favour development of the characteristic flavour and bouquet of flor sherry have been ascertained. Methods of using the flor yeast, other than the traditional method of growing it on the surface of wine in partially filled casks, are being tested.

(*b*) *Collection of Yeast Cultures*.—Further strains of wine yeasts from both local and overseas sources have been added to the collection. The yeasts are being tested by laboratory fermentation trials to determine their suitability for Australian conditions and requirements.

### 15. Dairy Products.

(*a*) *The Utilization of Skim-milk Solids*.—Increased use of the solids (not fat) of milk as human food is desirable for the population of Australia as a whole from the dietetic viewpoint, and for the dairy industry from the economic viewpoint. Work by the Dairy Research Section on this problem is along two main lines—the addition of milk solids to bread, and the development of other skim milk products, particularly the egg substitutes developed in Germany over recent years.

Studies on the incorporation of skim milk powder in bread have now been resumed, and the officer concerned has taken up his duties at the Bread Research Institute in Sydney, which is co-operating in the work. Amongst the first problems to be studied are the prevention of delay in fermentation time when milk solids are added to the dough, and the use of methods other than the simultaneous addition of fat to avoid reduction of loaf volume.

Work on the manufacture of egg substitutes from skim milk has also recommenced with the recent arrival from Germany of a scientist who has been closely associated with the development of these products.

(*b*) *Weed Taints in Butter.*—The quality of butter in Queensland is severely affected during the winter by off-flavours derived from weeds eaten by the stock. The field studies and feeding experiments referred to in previous years have been described in a report to the dairy industry soon to be published. Studies on the chemistry of the taint caused by *Coronopus didymus* have been continued. Strong evidence has been obtained that the main chemical compound responsible for this taint is benzyl mercaptan. Investigations have now begun on methods for eliminating this compound during the manufacture of butter. Unfortunately none of these methods has proved even as effective as the treatment with sodium hypochlorite, which did not give satisfactory results in field tests with strongly tainted cream, and is not permissible under present health regulations.

The other major type of weed taint is due to species of *Lepidium* which give rise to abnormal concentrations of indole and skatole in the milk. Studies have been undertaken to find the physiological mechanism by which the weed causes this change in the normal metabolism of the animal. Much of the experimental work was done on the goat, which is subject to precisely the same disturbance of metabolism by *Lepidium* as the dairy cow. Probable mechanisms, such as interference with the normal rate of excretion of these compounds, or influence on bacterial activity in the intestine, were proved not to be responsible. Less likely mechanisms were then investigated, but always with negative results. It appeared that the investigation would have to be abandoned, but recently some more positive results have been obtained and work is being continued. Valuable assistance in these studies has been given by the Schools of Bacteriology and of Biochemistry at the University of Melbourne.

(*c*) *Testing of Continuous Butter Processes.*—The Section has continued to co-operate with the Australian Dairy Produce Board and with the State Departments of Agriculture in testing continuous butter-making processes. Trials of the Australian New Way process, relating especially to the quality of the butter produced, the yield per pound of butterfat, and the costs of operation, were commenced at Glenormiston early this year and are now almost complete. The fact that these tests were made in Victoria has enabled officers of this Section to undertake a larger proportion of the work, which has been shared with officers of the Victorian Department of Agriculture.

Arrangements are also being made to test a new type of centrifuge, which may allow the application of processes of the Alfa type, hitherto restricted to sweet cream, to the neutralized acid cream which forms the bulk of raw material for butter manufacture in Australia.

Special attention was given to these new butter-making processes during an overseas trip by an officer of the Section. The detailed information gathered has been circulated to Departments of Agriculture, and officials of the Australian Dairy Board, and in a more general form to the industry generally.

(*d*) *Oxidized Flavour in Dairy Products.*—As a first step in studies on oxidized flavour in dairy products, experiments were undertaken to clear up conflicting statements in the literature on the nature and source of oxidized and other flavours which develop when milk is exposed to sunlight. Overseas workers on oxidized flavour have over recent years developed theories based on the flavour changes arising in milk which had been exposed to sunlight so that the ascorbic acid was partially or completely oxidized. In many of these experiments milk exposed to sunlight to allow complete destruction of ascorbic acid has been described as free of oxidized flavour. This is contrary to our previous experience, and our recent experimental work has confirmed our opinion. These studies have also given useful information on the relative importance in oxidized flavour of changes in the fat and in the protein of whole milk. A report on these studies is now being prepared for publication.

(*e*) *Mineral Sediment in Sweetened Condensed Milk.*—Investigations on this defect, which causes trouble in some Australian sweetened condensed milk, were continued during the year. Storage tests showed clearly that, as has also been found with unsweetened condensed milk, high storage temperatures greatly accelerated and increased the amount of deposition of calcium citrate. Analysis of milk samples from the factory concerned for calcium and citrate content throughout the year showed only minor variations, which were not linked with differences in the amount of mineral deposit formed. There was some evidence that conditions of manufacture giving rise to relatively coarse crystallization of the lactose also favoured formation of the mineral deposit.

(*f*) *Studies on Cheese Manufacture.*—Two major problems facing the cheese industry in Australia are the general low level of quality in our export cheese, and labour difficulties in manufacture which call for increased mechanization of the process. The Section intends investigating the bacteriology and biochemistry of cheese and, on completion of the weed-taint investigations, applying the techniques and equipment used in that work to a study of cheese flavour problems.

## XIII. FOREST PRODUCTS.

### 1. GENERAL.

Research aiming at the more effective utilization of Australia's timber resources is the province of the Organization's Division of Forest Products, located in Melbourne. This Division, which was first set up in 1928, has become the chief forest products research centre in Australia, and works in collaboration both with the Commonwealth and State forestry authorities and with allied laboratories overseas. Close contact with the timber and paper industries ensures the prompt recognition and use of research data, and much time is spent by research staff on advisory and extension work generally. The Division is also recognized as an important training centre for research workers in this field, and is providing facilities both for forestry officers from other countries and for advanced students here.

The Division of Building Research also has investigated the properties of fibre building boards (*see* Chapter XIV., Section 6 (*b*)) as bases for rendered finishes, and the Division of Entomology has carried out some work on timber pests (*see* Chapter IX., Sections 11, 12).

*Division of Forest Products.*—The work of this Division during the past year is described in the remainder of this chapter.

The continuing increase in the use of timber in Australia is reflected in the larger volume of inquiries and the many new problems submitted to the Division during the year under review. The greatly increased cost and difficulty of replacing wooden items such as cross arms and sleepers have emphasized the need for the utmost economy in timber design and for the treatment of timber to secure maximum life. A survey of the use of timber in house construction has accordingly been undertaken, and greater attention is being given to timber preservation in all its aspects.

As supplies of wood from virgin forests become depleted, the shortages are felt first in the higher grades of material. In Australia, the plywood industry is faced with a reduction in the supply of suitable logs from local sources and extensive importation has been necessary. One good source of veneer-quality timber is the ash-type eucalypts of south-eastern Australia, so far virtually untapped because of the refractory behaviour of this wood, particularly in the drying of the veneer. The difficulty was traced to prevalence of collapse in these species, and it is accentuated because the wood laid down by the tree at different times of the year varies widely in its susceptibility to collapse. This resulted in bad buckling of the veneer during drying, with attendant checking and splitting. The solution was found to lie in correct peeling procedure, drying under carefully controlled conditions, which have been determined, and reconditioning of the dry veneer with a special steaming treatment. During late 1949 the industrial use of the laboratory technique was demonstrated at a commercial plant, and has since been accepted there as standard practice. It has been estimated that as a direct result of adopting the recommended procedure, a minimum of 2,500,000 square feet of veneer per annum is being recovered at this one plant from previously discarded material on which some processing had been carried out.

The Division was represented at important international conferences during the year. The first was the Third World Forestry Congress in Helsinki in July, 1949. An officer of the Division was appointed rapporteur of Section V., Forest Industries. A paper on the general conditions applicable to timber testing was presented by an officer of the Division to the First Conference on Mechanical Wood Technology called by the Food and Agriculture Organization at Geneva in 1949. Most of the conclusions of this paper were accepted by the Conference, and adopted as a basis for the recommended international standard method of test. Other conferences included a meeting of the F.A.O. Technical Committee on Wood Chemistry which was held in Brussels in August-September, 1949. An officer of the Division also attended the First International Congress of Biochemistry, Cambridge, the International Colloquium on Macromolecules, and the Fifteenth Conference of the International Union of Pure and Applied Chemistry (Commission on Macromolecules), Amsterdam.

The Division is now recognized as an important training centre in forest products research and at present officers from Pakistan and Malaya are on prolonged visits. An officer of the Forest Research Institute, Nanking, completed a period of two years' training during the year.

The courses for forestry students and for architectural students of the University of Melbourne were continued and 40 senior students from the Australian Forestry School, Canberra, spent ten days in the Division.

Lectures on a wide range of subjects were given to audiences varying from technical school students to members of trade union organizations. The number of requests for information exceeded the 4,000 of the previous year, in addition to those covered by correspondence. Several exhibits for public exhibitions were prepared.

The annual Forest Products Research Conference was held in October, 1949, and the Annual Pulp and Paper Co-operative Research Conference in November, 1949. Both were held at the Division and they indicated that the co-operative activities of the Division are working smoothly. The help and co-operation of the paper companies, the Commonwealth Forestry and Timber Bureau, the State Forest Services, and the New Guinea Forests Department are gratefully acknowledged.

### 2. Wood Structure.

(*a*) *Wood Anatomy.*—A knowledge of the structure of timbers from Australia and neighbouring areas is of continuing importance, especially as a greater number of species is now being utilized. Therefore the investigation of the anatomy of various species from North Borneo, New Caledonia, and New Guinea, and of lesser-known Australian species has been a major activity. A card-sorting identification key based on macroscopic features is being developed for North Borneo timbers. The work has been greatly facilitated by the receipt of authentic specimens through the co-operation of the Forest Services concerned. The examination of the anatomy of the timbers of the Myrtaceae occurring in the south-west Pacific area has been completed and work has commenced on the timbers of several other families, including the Podocarpaceae. The revision of methods of identification for various eucalypt timbers is progressing.

The inclination of the spiral thickenings in tracheids of Douglas fir was investigated in relation to tracheid length. It was found that in the shorter tracheids near the centre of the tree the angle of the spiral in relation to the longitudinal cell axis was large, but became smaller in the longer tracheids; it was also smaller on the tangential than on the radial walls. This variation with cell length paralleled the changes observed in the spiral micellar orientation of the cell walls although the angles of inclination differed.

(*b*) *Cell-wall and Fibre Studies.*—(i) *Cell-wall Organization.*—The changes in organization with changes in cell length were investigated. In confirmation of earlier work, it was shown that the angle of spiral micellar orientation in relation to the longitudinal axis of the cell became smaller with increasing cell length. This was demonstrated for stems in which large cell-length variations occurred as a result of changes in growing conditions or of silvicultural treatment, and held both for gymnosperms and angiosperms. Correlations between cell length and such properties as shrinkage and tensile strength were also investigated, using the same material and following the changes through each successive growth ring. In this way the dependence of these properties on cell-wall structure was demonstrated and indications obtained of possible ways in which silvicultural treatments might improve the quality of timber in these respects. The investigation of the fine cell-wall structure of coniferous tracheids was continued, and the structure of the wall of developing cells studied, using X-ray diffraction methods and the electron microscope.

(ii) *" Skin " substance.*—The structural significance of the so-called " skin " substance of pulp fibres reported in pulp and paper literature was examined. It has been concluded that this substance cannot be identified with any one structural layer of the cell wall, but consists of portions of the primary wall and of the outer layer of the secondary wall. Its composition depends largely on the method of pulp preparation.

(iii) *Fibre Length Variation.*—In one tree of *Eucalyptus regnans* F.v.M. the fibre length varied from 0.5 mm. to 1.34 mm. depending on position in the tree. Shortest fibres occurred near the pith at all levels and the longest towards the outside of the tree at the 50-ft. level. In this tree, as observed in a large number of angiosperms with distinct growth rings, there was also a variation in length from early wood to late wood in the same growth ring at the one level. Where compression wood is found in gymnosperms the tracheid length drops markedly through the compression wood zone. In tension wood of angiosperms no significant difference in fibre length has been observed. In a specimen of *Pinus pinaster* which had been suppressed for approximately fifteen years and had then grown rapidly after treatment of the soil with superphosphate, it was found that the tracheid length dropped markedly immediately the rate of growth was increased by the treatment; it then rose again in the manner normal for a young stem.

(*c*) *Structure in Relation to Properties.*—(i) *Sapwood-Heartwood.*—Investigations of a number of trees with a narrow sapwood and coloured heartwood have shown that the ray cells contain substances in solution in the cell sap which are absent from the other living cells of the sapwood. In many woods these substances are tannins and can be turned into an easily observed solid by the use of formalin-acetic-alcohol as a fixative. By special techniques it has been shown that in species of *Eucalyptus, Nothofagus, Acacia,* and many other genera the tannins are in solution in the cell sap as long as the ray cells remain alive, and that some time before the ray cells die there is increased metabolic activity which results in the growth of tyloses, secretion of kino, and increased tannin production. On the death of the ray cells the permeability of the protoplasmic membrane alters and the tannins are set free to permeate the whole of the wood. On contact with the air—as the dead timber dries—they harden and become coloured, giving the heartwood its colour and increased durability, and rendering it difficult to penetrate with preservatives. Tannins have been absent from the sapwood trees available for study. The nature of the stimulus which causes first increased activity and finally death of the ray cells is now under investigation. In some trees death has been shown to be caused by fungal attack, in others it appears to be of dual origin, initially by injury or fungal attack, but afterwards through the toxic action of the released tannins. In some trees the ray cells live much longer than anticipated. In a myrtle beech (in which the annual growth rings are distinct enough to be counted) living ray cells were found in the 110th ring; in rings nearer the centre of the tree they had been killed by fungal attack.

(ii) *Brittle Heart.*—A survey of the occurrence of brittle heart in various timber species of Australia and neighbouring tropical areas has shown that it is more widespread than had been realized. It is rarely completely absent from any particular species, although in some its presence is restricted to the wood at or near the pith. The correlation of its occurrence with that of tension wood is being recorded.

(*d*) *Identifications and Identification Methods.*—Identifications totalled 2,000, including many eucalypt timbers used for crossarms. Numerous timber specimens from New Guinea, Northern Territory, and New Caledonia have also been examined and classified tentatively to assist botanical determinations. One hundred sets of the card-sorting identification key for commercial Australian timbers have been distributed to forestry authorities, forestry schools, and overseas laboratories.

(*e*) *Growth Studies.*—(i) *Beilschmiedia bancroftii.*—Analysis of data obtained over several years has indicated that in this species there is a period of active growth and one of dormancy each year; that the dormant period occurs during the tropical summer and coincides with heavy rainfall; that the parenchyma is laid down at the end of one growing period and the complete development of the parenchyma band completed at the beginning of the next growing period; that vessel elements within the parenchyma bands are much smaller in diameter than those within fibre bands, and that the parenchyma bands represent periods of slow growth and probably reflect carbohydrate deficiency.

(ii) *Other Species.*—Similar growth studies have been inaugurated on a number of rain-forest species, eucalypts growing in southern Queensland, indigenous coniferous species, and several exotic pines planted in Australia.

(*f*) *Siliceous Inclusions in Timber.*—Additional siliceous timbers have been examined and tests initiated to determine their resistance to attack by shipworms. A key for the identification of timbers in which siliceous inclusions occur has been prepared. Several non-resistant timbers have been impregnated with sodium silicate, and it has been found possible to produce a uniform distribution of silica throughout the wood. The silica will be precipitated in these specimens, which will then be tested against marine borer attack. Experiments have begun to determine the mechanism of uptake of silica by siliceous plants.

### 3. WOOD CHEMISTRY.

(*a*) *Lignin and Related Compounds.*—(i) *Homogeneity of Methanol Lignin.*—Resolution by means of paper partition chromatography using a butanol/acetic acid/water solvent system has revealed that methanol lignin contains one main fraction which gives the usual lignin reactions, but the spot of which presents a complex picture under ultra-violet light.

(ii) *Aldehydes from Eucalypt Lignins.*—The aldehyde mixture from nitrobenzene oxidation of eucalypts has been resolved by paper partition chromatography into vanillin, syringaldehyde, and a third, methoxyl-free, aldehyde. The latter has a small but measurable $R_F$ value identical with that of *p*-hydroxybenzaldehyde. A method has now been evolved for the quantitative separation of vanillin and syringaldehyde by means of paper partition chromatography.

(iii) *Determination of Hydroxyl Groups.*—The method for hydroxyl-group estimation previously described has been applied to various lignin samples with satisfactory results except on periodate lignin.

(*b*) *Wood Carbohydrates.*—(i) *Fractionation of Wood Nitrates.*—This investigation has now been completed and chain length curves for a number of fractionated cellulose nitrates have been prepared. Previous evidence of the occurrence in the cellulose chain of a periodic acid-sensitive link has not been confirmed. The study has thrown some doubt on the suitability of the methods now used for determining molecular-weight distribution of very high polymers.

(ii) *Polyuronides Associated with Lignin.*—A detailed chemical study has been begun of the polyuronide material which becomes soluble in water when *E. regnans* wood is cooked with methanol in order to extract methanol lignin.

(*c*) *Wood Hydrolysis.*—Study of the kinetics of the acid hydrolysis of wood has continued. X-ray diffraction photographs of hydrolysed wood holocellulose and cotton cellulose showed that the average breadth of the crystallites did not diminish as hydrolysis proceeded. It is considered that during hydrolysis the acid attacks the crystallites only on their surfaces. Assuming that the acid attacks only the lateral surfaces, it may also be concluded that, if the attack on cellulose is to simulate a first-order reaction, there must be an exponential distribution of micelle sizes.

(*d*) *General Wood Chemistry.*—(i) *Chemical Investigation of the Cambial and Neighbouring Zones of* E. regnans.—Examination of various zones has continued. With the exception of heartwood, which had an acetyl content of about 9 per cent., the acetyl contents of all zones were of the order of 4 to 6 per cent. Chlorite holocellulose contents varied from 33 per cent. in the cambial zone to 84 per cent. in the sapwood. The hydrolysates from the sapwood contained xylose in large amounts and glucose in small amounts, whereas those from the cambial zones contained small amounts of xylose and large amounts of glucose. The relatively large amount of glucose from the cambial zone probably indicates considerable quantities of short-chain (and amorphous) glucose polymers.

(ii) *Representative and Reproducible Samples of Wood for Chemical Investigation.*—Samples of the fifteen outer rings of heartwood have been taken from the butt logs of *E. regnans* at a constant height above ground level. In all, 30 samples have been collected in several Victorian forestry districts from trees which varied in age from 24 to 200 years. After conversion to longitudinal shavings 0.002-0.004 inch thick, the samples were exhaustively extracted with cold water, hot alcohol, and hot water. Mechanical agitation during the final hot-water extraction converted the shavings to small bundles of fibres suitable for analysis and for other chemical treatment. Analysis of the extracted samples is proceeding, after which they are to be blended to produce the first reproducible composite sample for chemical investigations.

(iii) *Chlorite Holocellulose.*—Temperature is a critical factor in this determination, and this, as well as the regulation of chlorite dosage, has been under investigation.

(*e*) *Extractives of Wood.*—(i) *Eucalypt Kinos.*—Jarrah (*E. marginata*) yields only part of its cellular kino on extraction with organic solvents. Wood which has been more finely divided yields more of the cellular kino, but by no means all of it. Various eucalypt kinos were successfully resolved by means of paper partition chromatography with phenol-base and alcohol-base solvents, and several of their major constituents were thus revealed as follows:—*E. calophylla* 12, *E. corymbosa* 13, *E. goniocalyx* 11, *E. radiata* 5, *E. regnans* 4, *E. obliqua* 3, *E. sideroxylon* 3. The elucidation of the constitution of aromadendrin is now almost complete, despite difficulties in preparing certain of its derivatives.

(ii) *Colouring Materials in* E. regnans.—A method has been developed by which more than 80 per cent. of the pigment from the methanol extract of *E. regnans* can be recovered. Some 141 g. of this pigment, representing 2.9 per cent. of the moisture-free weight of the wood, has been recovered. This is now being purified and will subsequently be converted to derivatives for analysis.

(*f*) *Pulp and Paper Investigations.*—(i) *Influence of Electrolytes.*—Investigation of the influence of anions on pulp and paper properties has been concluded. With one exception, sodium hexametaphosphate ("Calgon"), the effect of the electrolytes could be attributed to the sodium ion which was common to all the anions. Valence of anions did not affect their influence on sheet properties. The influence of sodium hexametaphosphate was outstanding, especially as the optimum concentration was only 1 milli-equivalent as compared with 4 to 8 milli-equivalents for the cations. In the presence of sodium hexametaphosphate, calcium retained by the pulp is replaced by sodium through ionic exchange and the pulp then becomes more amenable to beating and more sensitive to the effects of divalent and polyvalent cations. Investigation has also shown that the effects of high-valence cations on a pulp may be counteracted by the presence of sodium ion in the process water.

(ii) *Permanganate Number Determination.*—A comparative study of the methods for determining permanganate number used by the Division and by a paper-making firm indicated the importance of standardizing the method of sample preparation, and revealed other critical factors.

(iii) *Valley Niagara 1.5-lb. Beater.*—The use of an auxiliary device ensuring pulp circulation does not affect the beating performance of the Niagara beater but facilitates the processing of pulp at higher stock concentrations.

(iv) *International Correlation of Laboratory Beaters.*—In collaboration with Svenska Cellulosa A.B., comparative beating trials are being made on a range of pulps, using various laboratory beaters such as the Lampen mill, Valley Niagara beater, Banning-Seybold beater, and Aylesford beater. The investigation, which includes a comparison of techniques as well as sheet-making and paper-testing equipment, is subsidiary to a more comprehensive investigation which is being made simultaneously in Britain, Finland, Norway, and Sweden.

(v) *M.I.T. Type Fold Testers.*—Four folding endurance testers of the M.I.T. type have been compared and a new folding head has been designed and manufactured in the Division's workshops for one machine. The folding endurance test is subject to much variation, not all of which can be attributed to the folding head or to intrinsic characteristics of paper. Alignment of the test specimen in the instrument is highly critical and introduces an "operator" effect. Steps are being taken to provide mechanical aids for the purpose of reducing the "operator" bias.

(vi) *Inspection and Testing.*—Standard pulp-evaluation equipment, made in Australia under licence from the Technical Section of the British Paper and Board Makers' Association, has been inspected and certified by the Division. Precision guillotines and tearing-resistance testers, also made in Australia, have been checked and calibrated.

### 4. TIMBER PHYSICS.

(*a*) *Physical Properties of Wood and Related Materials.*—Shrinkage and density studies on Australian, New Guinea, and Pacific Island timbers were continued. The discrepancy between the volumetric shrinkage observed directly and that calculated from linear shrinkage values was investigated. In a study of the variation in shrinkage and density with height in the tree and distance from the pith, a definite decrease was found in both properties as the pith was approached and values varied with height in the tree. Density and shrinkage were fairly closely related at any one level. The ratio of tangential to radial shrinkage varied widely, but on the whole systematically, with position in the tree. Shrinkage determinations were made on both insulating and hard fibre building boards of Australian manufacture and various water-immersion tests were carried out. The effects of moisture content on the electrical resistance of such boards and of temperature and moisture content on the strength properties were investigated. Their thermal diffusivity and conductivity were determined, and the variation with moisture content found for insulating board. A mathematical solution of the problem of radiation error was developed and the error determined. The thermal properties of samples of bakelite and rubber were measured for the Division of Building Research.

Electrical moisture meter species corrections have been determined for a number of Australian and oversea timbers. Thickness corrections for use with moisture meters in testing veneers were determined for a typical softwood and hardwood. Investigations were begun on the use of electrical moisture meters at moisture contents above 20 per cent.

The investigation into the effect of variations in density, moisture content, frequency, grain direction and temperature on the dielectric properties of mountain ash was completed for specimens from one tree and the results analysed.

(*b*) *Studies of Creep in Wood.*—Additional tests are in progress on initially green mountain ash beams to determine the effect of shear on the increase in deflection under prolonged loading. Air-dry beams showed an increase in deflection of 2½ to 4 times the initial values in a year. These increases are much lower than for initially green beams. Failures occurred in seasoned beams loaded to 40 per cent. of the ultimate strength. Recovery tests on dry material indicated that at least 50 per cent. of the increase in deflection with time was due to elastic after-effect.

Dry beams were stressed to 20 per cent. of the ultimate strength and the modulus of elasticity of the material determined periodically by vibrational methods. The change in elastic modulus was not more than one or two per cent. The effects of temperature and moisture content variations of the wood on the change of elastic modulus under continued loading were also studied.

Tests on the two microscope creep instruments showed that factors such as temperature variation, position of the telescopes in their bushes, the direction of motion of the telescopes in focusing, and the tightness of the telescope clamps, caused significant errors. A standardized procedure has been developed to eliminate such errors. The effects on accuracy of the thickness and spacing of the telescope cross hairs, and the design and dimensions of the reference marks on the targets, are also being studied.

(*c*) *Battery Separators.*—Life tests have been made on batteries with separators of yellow carabeen and klinki pine. Electrical and mechanical tests have been commenced on Vanikoro kauri, jelutong, and Victorian-grown radiata pine. Following on the work of the Division, the Standards Association of Australia has issued a specification for wooden separators for lead-acid accumulators.

(*d*) *Dielectric Heating.*—A pilot-plant test was made to determine the economic possibilities of using high-frequency dielectric heating for setting glue in the manufacture of fruit cases from narrow boards. The work was done in co-operation with the Woods and Forests Department of South Australia, at their Mount Burr sawmill. The test was very successful and showed that the method is a better proposition economically than the mechanical jointer now in use.

(*e*) *Electrical Resistance Strain Gauges.*—The use in timber testing of the 48-channel strain indicator built for the Timber Mechanics Section was further studied. An unbonded strain gauge was built and its performance investigated. A satisfactory method for manufacturing a new type of bonded gauge, after Gaustaffsen, was found. Features studied during the year were the effect of drying time on strain factors, the change of gauge resistance with time, and the waterproofing of gauges. Full-scale tests were begun to compare strains indicated by mechanical extensometers with those measured by electrical resistance strain gauges under continuous loading.

(*f*) *Ultrasonics.*—Wood fibres in aqueous suspension were partially disintegrated by means of a 250-watt ultrasonic generator. Efficiency was improved by using a silver-plated quartz crystal with one side in contact with air.

### 5. TIMBER MECHANICS.

(*a*) *Studies of Mechanical Properties and Testing Methods.*—An Empire Timber Mechanics Conference held in North America in 1948 agreed that the standard shear test should be investigated, and assigned the investigation of the test to the Division; further experimental work has been carried out during the year and is still proceeding.

An "impact hardness" test, in which the reciprocal of the area of the impression made by a falling steel ball is taken as a measure of the hardness of the timber, is being developed. It is a non-destructive test and can be used on hard fibre boards which are too thin for the ordinary timber hardness test.

The correction procedure for moisture content recommended by the Empire Timber Mechanics Conference appears to be better than that which was in use in this laboratory. The practice now is to base adjustments of strength data for moisture content on relationships determined for the purpose, or failing that to use an assumed intersection point of 25 per cent. moisture content.

In an investigation of the variation of properties with height in the tree, compression and bending tests are being made on specimens taken over a length of 150 feet of a tree of *E. regnans*.

(*b*) *Species Testing.*—No abnormal difficulties were encountered in collection by the new sampling procedure, using one sample from each of a large number of trees, and it was found convenient and economical to collect other species at the same time. Specimens from about 350 trees were tested during the year, the species most largely represented being green messmate stringybark and dry silvertop ash, brown stringybark, white stringybark, New England blackbutt, and Douglas fir from New Zealand. Several species from New Guinea and two small samples from Fiji were also tested.

(*c*) *Silvicultural Tests.*—The new micro-tensile tester with a specimen of cross-section 1.5 mm. by 0.08 mm. was used in an investigation on two young trees of *E. regnans* of the same age and from the same locality. One, which was free growing, had a diameter of 5½ inches and the other had reached only 2½ inches. A very good correlation was obtained between cycles of test values and the growth cycles of the tree. The apparatus and the test are being investigated further before being applied directly to silvicultural work.

(*d*) *Long-time Connector Tests.*—There has been very little change in this investigation during the year. A few specimens have failed but the great majority are still carrying the load which has been on them for four or five years. The commonest method of failure was not by splitting of the end but by turning out and breaking across the connector, and a few additional specimens were erected with an extra bolt through the joint to prevent this. Indications are that this may allow the joints to fail by splitting, and if so some important deductions should be drawn from the experiment. In the original short-time tests on which the recommended working loads for connectors in Australian timbers are based, provision was made for some large-size rings. The air-dry set has now been tested, thus completing the experiment.

(*e*) *Columns.*—Duration of the load is known to greatly affect the strength of wooden columns and this factor is being investigated. Much preliminary work has been done, and a set of model columns of silver quandong has been tested under short-time loading. This set involved nine lengths, four nominal eccentricities, and two directions of growth rings. Preliminary work showed that the most effective measurements to take were the central deflection and surface strains under successive increments of load, from which an estimate can be made of the Euler load, equivalent eccentricity, stiffness, and modulus of elasticity.

(*f*) *Fibre Building Boards.*—The programme of tests of the strength of Australian insulating and hard boards has been completed, and the investigation of imported boards greatly extended. Minor investigations of the puncture resistance of board and of the static bending test for board have also been carried out.

(*g*) *Containers.*—An investigation similar to that conducted nearly twenty years ago on hemlock was made into the holding power of plain and special nails in radiata pine. The difference, however, is more than a change in the species as the wire used for the nails has been "improved". It is now smoother and the relative holding power of different nails has consequently been altered.

(*h*) *Timber in Housing.*—A survey has been undertaken of the current use of structural timber in houses in Australia. Tasmania, South Australia, and Western Australia have been visited and the other States will be included at an early date. Tests were also carried out on a patented framing anchor which is used in the United States, where most constructional timber is softwood. The recommended type of nail was not available and the substitute used was generally weaker than the anchor. On the whole, the test results were in reasonable agreement with United States figures.

### 6. TIMBER SEASONING.

(*a*) *Veneer Drying.*—A laboratory study of conditions necessary for producing good-quality dry veneer from the "ash" eucalypts has shown that optimum drying conditions comprise: Control of wet-bulb temperature at 95° F. to inhibit collapse, control of dry-bulb temperature at 150° F. to accelerate the drying rate and reduce checking, a high rate of air circulation to maintain maximum wet-bulb depression during drying, and reconditioning at the conclusion of drying to eliminate wrinkling, to close checking, and to recover sheet width. Under these conditions, dried veneer sheets of high commercial quality can be produced.

(*b*) *Vapour Drying.*—A study of the application of vapour drying to the seasoning of Australian commercial species was begun during the year. In this process, vapour from a boiling hydrocarbon is passed across the surface of the timber to be dried, the resulting mixture of water and hydrocarbon vapours being continuously removed from the drying chamber, condensed and separated. Work so far has been concentrated almost entirely on the study of the drying characteristics of the collapsing "ash" eucalypts and myrtle beech, which offer a most severe test of the process.

For these refractory species it has been established that operation under high vacuum with closely controlled low wood temperature is essential. Unfortunately, the latter condition tends to eliminate one of the chief advantages of vapour drying, speed of seasoning, and the former introduces other process difficulties. The most likely field of industrial application is in seasoning less refractory timbers. Experimental work in this field has been commenced.

(*c*) *Railway Sleeper Investigations.*—The sleeper replacement rate in Australian rail tracks is some 2,500,000 per annum, equivalent to an annual timber demand of some 85,000,000 super. feet, and any extension in sleeper service life must lead to worthwhile economy. A study of the causes of sleeper failure and of methods of increasing service life was, therefore, initiated.

Field surveys have shown that the prime causes of sleeper failure are mechanical and physical rather than biological. In particular, end splitting and brooming, deterioration at spike holes, and weathering degrade have proved the major factors contributing to the breakdown of hardwood sleepers. Work so far has been directed to studies of track conditions, including the effects of temperature and moisture, wheel loading, traffic density, ballast and drainage. The value of end coatings, surface protection, and anti-shrink treatments is also being assessed. A determination of the mechanical properties of standard rail fastenings has been made.

(*d*) *Kiln Drying.*—Laboratory work on the "stringybark" species was continued during the year. Drying schedules for brown stringybark, white stringybark and silver-top ash are now available for commercial use. Work on ramin, a North Borneo hardwood now being imported into Australia in some quantity, was completed. An examination of the drying characteristics of 2-in. thick messmate stringybark required for a Tasmanian hydro-electric scheme was carried out. A study of the chemical seasoning of myrtle beech textile roller blanks was made. Encouraging reports on the industrial performance of the rollers was received.

(*e*) *Kiln Design and Plant Layout.*—Continued assistance in pre-drier design and seasoning plant development was provided to industry. Additional studies on pre-drier performance were made, and earlier designs modified. Some 290 drawings covering design details for the installation of timber-seasoning kilns, veneer driers, and plywood and panel stock redriers were prepared for some 36 companies during the year. Where necessary, appropriate specifications and lists of materials were also provided. Surveys of plant performance were carried out in Queensland, Victoria, Tasmania and Western Australia. Production studies were made and recommendations prepared from the resulting analyses. Further attention was given to the design of the McCashney sawdust burner and drawings were supplied to industry. This unit helps greatly to eliminate fire hazard at wood processing plants.

(*f*) *Building Materials.*—Laboratory studies of the major process variables encountered in the development of wood-waste/synthetic-resin combinations were largely completed. Work on these materials to give core stock, moulded products, and, under special conditions, hard board, would seem justified. Inquiries concerning the properties and application of wood/Portland-cement mixes were frequent, and advice was given as appropriate.

(*g*) *Other Investigations.*—An analysis of data from the study of a portable log edger sawmill of new design was completed, and the results reported. Miscellaneous subjects on which information was sought by Government authorities, industry, and the public included the drying of case stock, collapse in timber and reconditioning, drying schedules for imported and native species, shrinkage in wood, mill-waste disposal, chemical seasoning, waste wood as a boiler fuel, the drying of wood wool, the crazing of plywoods, kiln construction and drying costs, degrade in timber, moisture meters, timber handling, kiln maintenance, furnace-type kilns, wooden rules, leather softening, the cause of failure in tool handle stock, the drying of artificial limbs, protective surface finishes, the failure of wooden components in cash registers, paper roll core plugs. The correspondence course in kiln operation was continued.

### 7. TIMBER PRESERVATION.

New projects include a study of the toxicity and permanence of various water-borne preservatives likely to be suitable for pressure treatment of pit-props and other colliery timbers, and a study of the toxicity of creosotes obtained from gasification of Victorian brown coal.

(*a*) *Field Tests.*—Variously treated timbers exposed to termite attack near Canberra, and to decay attack near Melbourne, have been inspected. Specimens were placed also at Belgrave, Toolangi, Highett, and Ballarat in Victoria to test relative decay hazards for future field test installations. (*See* also work in the Division of Entomology, Chapter IX, Section 11.)

(*b*) *High-pressure Treatment of Eucalypt Timbers.*—Construction of a new high-pressure cylinder to treat timber at pressures up to 1,000 lb./sq.in. is nearly complete and the assembling of some 2,500 sleepers for treatment and service testing in Victoria has begun.

(*c*) *Lyctus Investigations.*—The momentary-dip treatment of green veneer in cold solutions of boric acid or borax has proved entirely successful in practice and is being operated by an increasing number of commercial plants. The addition of preservatives to the glue to prevent *Lyctus* attack is being recommended for the present only for plywood to be used for temporary purposes, or for plywood which will be effectively sealed on all surfaces with paint or other permanent sealing coat. Low concentrations of benzene hexachloride (¼ lb./1,000 sq.ft. of single glue line) are recommended where protection for not more than three years is required. The estimated chemical cost of this loading is 1½d. to 2d. per 100 sq. ft. of three-ply. Tests to determine the permanency of this treatment are continuing and the third inoculation of test pieces with *Lyctus* beetles has been made. In co-operation with the Division of Entomology (*see* Chapter IX., Section 12 (*d*)) tests on the nutritional requirements of *Lyctus brunneus* were continued. A further set of specimens has been impregnated with nutrients and is at present being subjected to *Lyctus* attack. Toxicity to *Lyctus* of a number of water-soluble preservatives at different loadings in various susceptible timbers is also being investigated, to determine more precisely the percentage of chemical required for *Lyctus* control in timber species of different densities.

(*d*) *Metallic Naphthenate Preservatives.*—Laboratory tests indicate that crude naphthenic acids are less toxic than the corresponding copper naphthenates. Toxicity of the crude acids increases with acid number, and toxicity of the copper naphthenate increases with the percentage of copper present. Toxicity tests are now being made on the purified acids and the copper naphthenates prepared from them.

(*e*) *Preservative Treatment of Crossarms.*—A survey in Western Australia showed that in karri arms removed from service, failures caused by decay and termite attack totalled 71 per cent. for all localities, while the corresponding figure for jarrah was 33 per cent. Splitting and weathering were the major causes of failure of jarrah arms, causing approximately 40 per cent. of failures in all localities. As a result of discussion with the Postmaster-General's Department and the State Electricity Commission of Victoria, a number of arms will be treated in the new high-pressure cylinder, and it is expected that treatment will effect considerable savings in replacement costs. A survey of the causes of crossarm failure is now in progress in New South Wales and Queensland.

(*f*) *Timber Mycology.*—Comparison of the decay resistance of Australian timbers by the use of accelerated laboratory decay tests has continued. A suitable technique for soil-jar decay tests is being sought, and a number of widely used methods for measuring decay resistance are now being tested. Preliminary results indicate that the soil-jar technique is preferable to the agar-culture technique. Various species and strains of wood-destroying fungi are being tested to select the most suitable strains for long-term tests, and collection of a number of Australian timbers is in progress through the State Forest Service.

Preliminary studies have indicated that the growth of test fungi on autoclaved sawdust may give a rapid indication of the decay resistance of timber. Investigations on water-soluble extractives from eucalypts showed that several eucalypts possess moderately toxic extractives, but no correlation of the amount and toxicity of these extractives with decay resistance was demonstrated.

A reference collection of fungal cultures to be used for identification purposes and to provide suitable test fungi is being built up. Seventy new cultures were isolated from fruiting bodies or from decayed wood, and 77 cultures were obtained from oversea collections during the year. A complete catalogue of the collection, which now contains 388 cultures, mostly from the Polyporaceae, has been prepared.

(*g*) *Diffusion Studies.*—The diffusion behaviour of electrolytes through wood may be explained if wood is regarded as a negatively charged, semi-permeable, selective medium. The extent of this selective activity is affected very considerably by wood density, anatomical structure, and orientation with respect to the direction in which diffusion takes place. Eucalypt species of high density exhibit these effects to the greatest extent, and it has become apparent that these species, owing to fundamental properties, cannot be treated by diffusion by simple variation in technique.

(*h*) *Other Investigations.*—The test to be made in co-operation with the Department of Scientific and Industrial Research, New Zealand, to determine the susceptibility of *P. radiata* to the Anobium borer, has been temporarily deferred because the test panels were not sufficiently infested with Anobium. The Department of Scientific and Industrial Research reported that oviposition was very light and it will be necessary to repeat attempts to infest the panels during the next flight period. In tests undertaken jointly with the Division of Entomology, a number of species of yellow carabeen were impregnated with pentachlorphenol and tested by the laboratory colony method for resistance to *Coptotermes lacteus* and *Eutermes exitiosus* species. Concentrations of pentachlorphenol as low as 0.27 per cent. gave a high degree of protection against *Eutermes exitiosus,* but with *Coptotermes lacteus* appreciable attack occurred at concentrations as high as 2.16 per cent. Preliminary test results strongly indicated that timber density was not an important factor in determining resistance to termite attack. Impregnation of timber with silica for tests of marine borer resistance was undertaken in co-operation with the Wood Structure Section.

### 8. Veneer and Gluing.

(*a*) *Veneer and Plywood Manufacture.*—(i) *Veneer.*—Veneer was cut from logs of radiata pine, slash and loblolly pines, hoop pine, alpine ash, mountain ash, and a New Guinea species of *Podocarpus.* Observations were made to determine the best conditions for cutting veneers of thicknesses between 1/133 inch and ½ inch, but most attention was devoted to production of 1/16-in. and ⅛-in. veneers as commonly employed commercially for plywood production. The effect of heating logs before peeling on veneer quality was studied in conjunction with variations of lathe-knife and pressure-bar settings. In conjunction with State Forestry Departments, investigations have been commenced on plantation-grown hoop pine and radiata pine to determine the period which elapses between pruning of branches, occlusion of the stub, and production of clear wood unaffected by previous treatment. Some investigations on the peeling and utilization of knotty pine veneer were conducted and assistance given in the preparation of a draft specification for peeler logs of radiata pine. As a result of studies on alpine ash veneer manufacture it is probable that at least one plywood plant will be established in Victoria to use this species for veneers.

Advice concerning equipment and recommendations for veneer and plywood plant layouts were given to prospective manufacturers.

(ii) *Immunization of Plywood against Lyctus Attack.*—An investigation to determine the effect of impregnation with boric acid or borax on the wet and dry strength of waterproof plywood with a phenol-formaldehyde film glue was completed. This method cannot be recommended for immunizing veneers for waterproof plywood manufacture.

(*b*) *Gluing Investigations.*—(i) *Gelation of Casein-Alkali Systems.*—Work on the fundamental mechanism of gelation in systems containing protein and alkali has related chiefly to casein.

The use of viscosity methods to follow changes in the shape of protein molecules occurring on treatment with sodium hydroxide has been extended to cover the effects of pH, protein concentration, and time of treatment; results indicate that denaturation, in the configurational sense, is not a significant part of the gelation mechanism. X-ray data support this view. Solubility studies have also been made on alkali-modified casein, by determining protein nitrogen in the filtrates from buffered systems containing protein at a concentration exceeding the solubility. Solubility may be permanently increased by treatment under moderately alkaline conditions, but at high pH is decreased to a marked extent. The heat of solution remains practically constant. Light absorption also has been used to characterize the molecular changes resulting from alkali treatment and to relate them to the gelation process.

The variation of gelation rate with pH in casein dispersions containing only the protein, sodium hydroxide, and water has received attention. The phenomenon of spontaneous isothermal gelation, without solvent removal, has been found to be specific to two pH ranges, in each of which a different mechanism appears to predominate. At high pH (*c.* 13) there is evidence for the formation of covalent bonds less alkali-labile than at least some of the peptide linkages. The gel network is loose, swells readily in polar solvents, and is easily deformed elastically under shear stress, but is chemically stable over a very wide pH range, i.e., gelation is irreversible. In the lower pH range (*c.* 10) the gels are far less stable.

Various methods have been used to block specific free groups in the protein molecule to determine whether gelation can be inhibited. Particular attention has been given to the guanidino group of arginine, and relative estimations of arginine have been made colorimetrically on hydrolysates of untreated casein, gelled material, and various other preparations. Determination of amino acids in the hydrolysates has been commenced, using paper partition chromatography.

The concepts and techniques developed in this work have been applied to methods of production of casein and their influence on the properties of the protein for industrial purposes, to the use of other proteins in adhesives, and to the stability of glued joints under various conditions of service.

(ii) *Hydrochloric Acid Casein for Glues.*—Investigation of the processes for manufacture in Australia of hydrochloric acid casein were completed and recommendations made for suitable formulae for its commercial application as a major constituent of plywood glues.

(iii) *Other Investigations.*—The possibility of utilizing animal blood or blood by-products as adhesives in the plywood industry has been explored, and the information obtained was used in developing a wood waste-blood board which gives some promise of commercial application. Tannin-formaldehyde adhesives made by the Division of Industrial Chemistry were investigated as new and possibly cheaper hot-setting glues for waterproof plywood. Several commercial adhesives were tested for plywood and wood assembly gluing. Studies were made also on gluing properties of several woods and on problems of gluing veneers of several species, especially the unsatisfactory adhesion of laminations of heavy eucalypt woods when gluing is delayed for some time after machining. The circumstances under which face veneers are badly stained by glue, and some methods for removing stains, were investigated.

A method for manufacturing plywood from green veneers which showed some promise for manufacture of the lower grades of plywood was investigated on a limited scale. Since the setting of casein and synthetic resin glues is accelerated by heat, the use of electric-resistance strip heating was investigated, special attention being given to flush door manufacture. Experimental work showed that by using this method production could be greatly increased, and under winter conditions in Victoria output might be increased twenty-fold as compared with cold pressing.

(*c*) *Standards.*—Assistance was given to the Standards Association of Australia in the drafting of an Australian standard for waterproof plywood, and the drafting of a revised standard for plywood for general purposes was commenced. The Officer in charge of the Section was appointed convenor of a panel to review existing Australian standards for adhesives for wood and plywood and to draft specifications to meet current needs of the plywood, furniture, and allied industries.

(*d*) *Assistance to Industry.*—Other subjects on which advice and information were given were: bending of plywood for suitcase manufacture, corestock manufacture, furniture manufacture, laminated construction for boats, skis, tennis racquets, diving boards, and axehandles, slicing of case shooks, gluing of metal and strain gauges to wood, insulating-sandwich construction proposed for Antarctic expedition buildings, match and matchbox manufacture.

## 9. TIMBER UTILIZATION.

(*a*) *Timber Uses.*—Many requests for information and assistance with problems connected with timber utilization were received from the timber industry, private individuals, and governmental and semi-governmental organizations. Information was supplied on the suitability of various timbers for the following: architraves, archery bows, artificial limbs, bench tops, boat building, body building (motor car), blinds (venetian), brushware, cases (apple), churns (butter), cooperage (tight), contact breaker arms, decking, dip sticks (alcohol), draughting instruments (T-squares), dry-cleaning equipment, dowelling, duckboards (electroplating plant), fence posts, fire escapes, flooring, flush-panel doors, food trays, furniture, handles (axe and tool, also laminated), house stumps, hand rails, harvesting equipment, ice hockey sticks, joinery, ladders, log cabins, machinery components (laundry), massage sticks, matches, metal polishing (rumbling), mining timbers, neutralizing boxes, oars, pegs, pencils, rollers (fruit-sorting tables), rounder plates (leather), roofing (insulated cool store), rules (folding and scale), shingles, skewers, skis, shoe heels, surf boats, tables (pastrycooks), tank stands, tank screens (aquarium), Turkish bath seats, turnery, transformers (oil-immersion), vats (acid and brine), water-cooling towers, windows, wire-winding battens, wood flour, wood wool.

Tests were conducted on the corrosive effects of different timbers on aluminium roofing materials.

(*b*) *Manufacturing Processes.*—Sawmill layouts and details on characteristics of equipment were supplied to operators desiring to improve existing sawmills or to establish new ones. A course of instruction in sawmill engineering was given to members of the timber trade in Queensland. Principles of efficient use of devices such as saw-bench gauges, docking saws, docking gauges, log cross-cut saws, and conveying equipment were published in an endeavour to widen their application. A paper on sawmilling practices was presented at an industry conference. Assistance was given to several firms in re-organizing timber handling methods.

(*c*) *Waste Utilization.*—Investigations were continued on the factors influencing the quality of pulps produced in an attrition mill, and on the properties of boards produced from such pulp by hot pressing. The disintegration of raw chips, and of chips boiled and steamed, with various settings of attrition plates of coarse and fine patterns was studied. The effect of coarse grinding, followed by single and multiple re-grinding with fine plates, was examined and attempts made to assess the merits of beating in a rod mill and a ball mill in lieu of re-passing through the attrition mill. The range of temperatures and pressures and duration of pressures has been extended in studying the effect of pressing conditions on the strength of boards. Inquiries on the equipment used for the commercial manufacture of fibre boards were dealt with. Investigations were commenced on bonding of sawdust-casein and sawdust-protein mixtures. Techniques for mixing and pressing the latter were developed and promising results obtained within a temperature range of 260-300 ° F. and pressures of 200-800 lb./sq.in.

(*d*) *Sawing Studies.*—Initial trials have been run on equipment designed to permit study of the fundamentals of circular sawing, particularly to relate tooth characteristics with energy consumed. Field studies on chain saws were concerned with the factors affecting sawing rate, blunting rate, and power requirements. Negative hook was shown to have an advantage for chains used to cut dense timbers. Several forest workers were trained in the preparation and operation of chain saws, demonstrations and addresses were given, and data published.

(*e*) *Standards.*—Collaboration with the Standards Association of Australia on all matters pertaining to timber standards was continued. Executive duties were performed for the Timber Industry Committee, technical liaison work was continued with sectional committees, and an active part taken in preparing drafts of several proposed standards. Information on Australian grading, timber testing, and nomenclature was forwarded to the F.A.O. Regional Conference at Dalat, Indo-China. Progress was made in revising the grading rules for timbers of southeastern Australia. Agreement was reached in the Victorian Sectional Committee on Wood Technology on new rules for unseasoned dressing-quality sawn timber, in select grade and in standard grade, for building scantling, and for case timber. Consequent changes in the descriptions for milled flooring, milled lining, and milled weatherboards of these grades were drafted. Committee drafts were also prepared for a grade of rediata pine flooring and fibreboard butter boxes. Progress was made in revising standards relating to plywood, marine plywood, nomenclature of Australian timbers, and codes of practice for single-story timber buildings, wooden windows and doors, and door frames. Preparation of a glossary of standard terms and definitions used in forest products research in the British Commonwealth was continued. A working plan for studies on the quality characteristics of sleepers was prepared. Field studies were continued on the influence of defects on the stiffness of building timber. Grading lectures and demonstrations were given at a timber industry conference.

## XIV. BUILDING.

### 1. General.

Recent steps to import prefabricated houses into Australia have sharply emphasized the fact that present supplies of building materials and man-power are far from meeting the swollen post-war demands. Research is urgently needed to enable the materials available to be more effectively and economically used and to improve their overall quality so as to minimize time spent on repairs.

In Australia the two main centres for building research are the C.S.I.R.O. Division of Building Research at Highett, Victoria, and the Commonwealth Experimental Building Station, in Sydney, under the Department of Works and Housing. Their work is complementary, the C.S.I.R.O. Division investigating the properties and uses of building materials and the C.E.B.S. problems of design, construction, and performance of buildings. They work in close collaboration with one another and with the building trade.

Work on timber is concentrated in the Division of Forest Products and is outlined in Chapter XIII. Studies on house foundations are being carried out by the Division of Soils (*see* Chapter II., Section 4) and work on cement and ceramics by the Division of Industrial Chemistry (Chapter XVII., Section 3).

*Division of Building Research.*—In May, 1950, the status of the Organization's former Building Research Section was raised to that of a Division. This action has not entailed any change in functions or scale of activities but the appointment during the year of additional research officers has enabled existing work to be intensified and some new work to be begun. However, the work of the Division is still seriously hampered by the difficulty of obtaining research staff.

The contact established with various branches of industry in previous years was strengthened by the activities of the Building Research Liaison Service of the Department of Works and Housing. This Service has been particularly helpful in co-operating in the organization of surveys in the various States of troubles associated with flat roofs and with the decoration of fibrous plaster. Active participation in the work of the Standards Association of Australia on the preparation of specifications and codes relating to building has continued.

Considerable technical assistance was given to the building industry, some 1,800 inquiries (an increase of about 80 per cent. compared with the previous year) having been answered.

Five of the research staff obtained overseas experience during the year; one studied in the United States of America as a research student, the others visited research laboratories and other organizations concerned with building in Great Britain and Europe as well as spending some weeks at the Building Research Station of the Department of Scientific and Industrial Research in Great Britain. The Division is greatly indebted to that Station for its generosity in making the time and experience of its staff available to these and other officers of the Division, and also for the invaluable assistance and advice which it has freely given for some years past.

The Chief of the Division, who is the Australian delegate to the Réunion des Laboratoires d'Essais et de Recherches sur les Matériaux et les Constructions, was represented by officers of the Division at the 1949 and 1950 Conferences of the Réunion in Zurich and Liége respectively; an officer also attended the 1950 International Acoustics Conference in Marseilles.

### 2. Physical and Mechanical Testing Laboratory.

(*a*) *Testing.*—Some 1,100 mechanical and physical tests were made for other Sections of the Division.

(*b*) *Weathering Studies.*—Work on the measurement of solar radiation, as an aid to the understanding of deterioration of building materials and to the development of accelerated tests to assess durability, has been continued. Progress was made with the design and construction of an instrument for recording the intensity of solar radiation, and an absolute pyrheliometer based on the Angstrom pyrheliometer was designed for its calibration.

(*c*) *Concrete Roofing Tiles.*—Further work was done on the mortar surface finish for roofing tiles and equipment for its application.

(*d*) *Damp-proof Course Mortars.*—Investigation of the properties of these mortars, which was undertaken to assist in framing an Australian standard specification, was continued. Performance data, however, are few, and the relation between mortar permeability and brick properties is a complex one. Further, the possibility of soil salts crystallizing at the damp course will have to be examined, following the observation that the damp-proof course mortars had completely failed in a number of houses, some only fifteen months old. Much work remains to be done before these materials are fully understood.

An important fact already evident from the investigations is that whilst water-repellent agents, in the proportions used in damp-proof course mortars, have little effect on the permeability of mortar cast in non-absorbent moulds, they have a much greater waterproofing effect on mortars cast on absorbent materials such as bricks.

(*e*) *Properties of Australian Building Sands.*—The aim of this project is to classify the building sands of Australia; four Victorian sands were examined during the year.

(*f*) *Experimental Stress Analysis.*—A rapid technique for making electrical resistance wire strain gauges was developed, and indicating and calibrating equipment was constructed.

(*g*) *Effect of Mechanical Properties of Floors on Comfort.*—Work on this project has been started and progress reported in Section 5 (*c*) (i) of this Chapter.

### 3. CONCRETE INVESTIGATIONS.

Experimental work on foamed concrete has been continued, but the fundamental work on air-entrainment recorded in the last Annual Report was transferred as from 1st July, 1949, to the Division of Industrial Chemistry.

Investigations have also been undertaken on the theory of rupture of concrete, problems associated with the durability of concrete in Australia, and the variation in strength of test specimens due to changing atmospheric conditions during their preparation.

(*a*) *Foamed Concrete.*—Experimental work to encourage large-scale local production of foamed concrete, a strong light-weight building material with good heat-insulating properties which is extensively used in certain parts of Europe, has continued. Data on its preparation, properties, and uses are being obtained.

The following methods of preparation are being examined:—Mechanical foaming (pre-foaming or combined mixing and foaming), chemical foaming, and combined mechanical and chemical foaming. Concretes with densities ranging from 15 to 120 lb. per cubic foot (ordinary concrete is about 145 lb. per cubic foot) have been made.

The properties of foaming agents have been studied and some new foaming agents and setting accelerators have been produced. An air-displacement meter suitable for use in the laboratory or in the field has been devised for measuring the gaseous content of foamed concrete mixes.

The effects of variations in the materials and methods used in manufacture (e.g. water-cement and cement aggregate ratios, fineness moduli and varieties of aggregates, admixtures, mixing, and curing) are being investigated.

(*b*) *Theory of Rupture of Concrete.*—Fundamental research is needed to establish an adequate theory of rupture of concrete, a basic problem in all concrete and reinforced concrete design. Replies to a questionnaire circulated in the United States of America and Europe indicated that practically no work had been done on the problem so far.

(*c*) *Durability of Concrete.*—Inquiries are being made to ascertain whether the life of concrete structures in Australia has been less than expected, and consideration is being given to methods of assessing durability from laboratory tests.

At the request of the Department of Works and Housing, a study is being made of the disintegration of two sea walls on the Victorian coast, and advice has been given on future construction in the area.

(*d*) *Strength Variation in Test Specimens due to Changing Atmospheric Conditions.*—The concrete laboratory is to be air-conditioned, but in the meantime the effect of day-to-day variations in atmospheric conditions on the results of strength tests is being studied. The information obtained should be useful to testing laboratories which are not air-conditioned, and will be helpful in interrupting the results of tests on specimens taken in the field.

### 4. MASONRY INVESTIGATIONS.

(*a*) *Clays and Clay Products.*—(i) *Survey of the Heavy Clay Industry in Australia.*—The survey of brick, tile, and pipe plants throughout Australia was continued, plants being visited in north and south Queensland, South Australia, New South Wales, and Victoria during the year. In addition, a number of clay and shale deposits were inspected.

The quality of bricks in Australia is very variable. In many yards it is first-class, but in others, despite excellent raw materials, it is unreliable through lack of proper control. On the whole, the quality of sewerage pipes and roofing tiles is good.

The shortage of all clay building units is everywhere acute, and expansion of the brick and tile industries is essential if present and future requirements are to be met.

Once again, however, it must be emphasized that only an extensive re-organization of many existing works, as well as the erection of new works operating on modern lines, will overcome these shortages. The shortage of labour is a serious factor in retarding output and is likely to continue until working conditions are made as attractive as those in other heavy industries. Wherever possible the works should be mechanized throughout, from the initial clay winning to the final burning of the ware.

(ii) *Clay Technology.*—The work in the heavy-clay pilot plant has steadily increased. Tests have been made on clays or shales from seven localities in Queensland, three in New South Wales, four in Victoria, and one each in South Australia, Tasmania, Australian Capital Territory, and Northern Territory.

(iii) *Technical Advice.*—The erection at Granton in Tasmania of the Granton Brick Company's plant, which was designed by the Division, is now well under way. Advice has been given on the re-organization of this company's subsidiary plant at Dover.

At the request of the Department of Works and Housing, the Division prepared the basic design of the proposed new brick works at Canberra. The detailed working plans are now being prepared by the Department of Works and Housing in co-operation with the Division.

Full reports on the clays and plant layout and sketch plans of tunnel kilns have been prepared for three country brick manufacturers in Victoria, each of whom contemplates erecting a plant to produce 5,000,000 bricks per annum.

As a result of visits to sites in five States and labora-ory tests of the raw materials available, advice on election of machinery, plant layout, and tunnel kiln esigns has been given to companies that are considerng redesigning old, or erecting new, works on modern ines.

Difficulties in drying green clayware, accentuated by ecent extremely wet weather, have caused tile and pipe nanufacturers in Sydney to seek advice on the installaion of mechanical humidity dryers. Plans for both unnel and chamber types have been prepared and letails discussed with the companies concerned.

(iv) *Clay Research.*—The geological origin of the Australian heavy-clay deposits is being studied and an attempt is being made to correlate the various types of exposure. Data from the pilot-plant investigations are steadily accumulating and are giving a general guide to the basic properties of the clays. The important types are being chemically analysed and when the optical, X-ray, and differential thermal analysis equipment is assembled, a detailed mineralogical examination of these will be undertaken.

(*b*) *Lime and Lime Products.*—(i) *Survey of Australian Lime Resources and Industrial Plants.*—More information on the commercial limestones of Queensland, New South Wales, Tasmania and Western Australia has now been obtained and lime plants visited at Rockhampton, Queensland, throughout Tasmania and near Perth.

Advice to firms on the installation and operation of plant for manufacturing lime has been continued.

(ii) *Lime Research.*—A basic study of lime and its hydration products has begun and the literature on this subject is being surveyed with special attention to the preparation and soundness of hydrated lime.

(iii) *Carbide Waste Lime in Mortars.*—It has been shown that the low strength and lack of durability of mortars incorporating carbide waste limes can be attributed to the large amount of sulphides in the waste limes.

(*c*) *Silica Bricks.*—(i) *Sand-lime Bricks.*—Advice and assistance on the manufacture of sand-lime bricks have been given to six firms in five States. The use of insufficiently hydrated lime in one works was shown to be the cause of difficulty in producing uniformly satisfactory bricks. A recommendation was made that the lime should be autoclaved before use, and adoption of this procedure appears to have overcome the trouble. Other firms contemplating the manufacture of sand-lime bricks were advised to use quicklime.

Sands and limestones to be used as raw materials in two proposed works, one in Victoria and the other in Western Australia, were tested to determine their suitability.

(ii) *Silica-silicate Bricks.*—An investigation was made for a Victorian company to determine the correct burning temperature and the best proportions of magnesium oxide and sodium silicate as binding materials for silicate-bound bricks.

(*d*) *Masonry.*—(i) *Efflorescence.*—The study of efflorescence has been continued. Further data confirmed earlier findings that the main component of the efflorescence in the masonry examined in South Australia was sodium sulphate, and that this originated in the cement used for the mortars. The efflorescence consisted of almost pure sodium sulphate, but the aqueous extract from the cement contained virtually equal quantities of sodium and potassium sulphates, so that apparently some form of selective migration or adsorption took place in the masonry.

(ii) *Deterioration of Natural Stone.*—More examples, chiefly in old stone buildings near the coast, of the deterioration of natural stone masonry have been reported. The most serious deterioration was that of a war memorial erected after the first World War.

(*e*) *Crystallographic Investigations.*—A crystallographic laboratory is being set up to permit a more basic approach to the problems associated with building materials. In the meantime this Division is indebted to the Division of Industrial Chemistry for the use of its equipment. Two cases of concrete failure, and also the nature of sulphide stains on fibrous plaster, are being investigated.

### 5. SURFACING MATERIALS.

(*a*) *Gypsum Plaster.*—Although some work has been carried out on the production of gypsum plaster, most attention during the past year has been given to methods of testing the finished product.

(i) *Consistency.*—The slump method of determining the consistency of plaster slurries, which has replaced the former Vicat test in S.A.A. Interim Specification No. 317, has been examined. Its reproducibility was poor, but was considerably improved by oiling the glass plate over which the slurry was allowed to flow. The results still appeared to be affected by atmospheric temperature.

(ii) *Particle Size.*—An important property of plasters is the size distribution of the particles of which they are composed. Measurement of this by sieving was unsuccessful and an apparatus which determines the size distribution by differential settling in a stream of gas is being developed. The chief difficulty with this apparatus is the tendency of the finer fractions to stick to the walls of the glass tubes. This was partially overcome by maintaining a temperature difference between the gas stream and the tube walls, but since the causes of the sticking are chiefly electrostatic, better results were obtained by using radioactive materials to ionize the gas stream and so make it conducting.

(iii) *Setting Time.*—Preliminary work has shown that the heat generated during the setting of plaster can probably be used for estimating setting time, and an adiabatic calorimeter has been built to measure the heat of hydration.

(iv) *Weatherproofing.*—Work has continued on the problem of weatherproofing the gypsum slab walls used in prefabricated houses in some of the drier parts of South Australia so that their use may be extended to areas of higher rainfall. Various paint treatments have been tried without success.

(v) *Advice to Industry.*—Suggestions for the improvement of a plaster mill were made at the request of the owners, and advice on the design of a mill was given to a potential manufacturer. Analyses of gypsum samples were carried out for another prospective plaster manufacturer.

(*b*) *Bathroom and Kitchen Wall Surfaces.*—(i) *Laboratory Examination of Wall-surfacing Materials.*—When commercial materials were examined for resistance to soap and alkalis it was observed that not only the degree of resistance but also the type of failure varied widely, and that when solutions of sodium carbonate were substituted for soap (at chemically equivalent strengths) the rate of attack, despite increased alkalinity, was often less. Films of air-drying alkyd enamel, when subjected to the action of solutions of several synthetic detergents, underwent failure similar to that produced by soap solutions. Experiment showed that finely ground alkyd resin film material could be dissolved in considerable quantities by such solutions. These results, together with the known low hydrolysis alkalinity of soap solutions, confirm the view that the alkalinity of at least some soap solutions is not the sole cause of attack.

(ii) *Experimental Installations.*—Field trials of polystyrene tiles showed that they could be installed much more quickly than ceramic tiles and when given reasonable maintenance did not deteriorate in appearance. Heat warping was not a serious hazard if reasonable precautions were taken. The white lead putty type of mastic supplied with the tiles was not satisfactory. Its consistency was too thin for easy use and it soon failed where it was exposed to heat or where the tiles were installed on materials, such as hardboard, which expand appreciably on absorption of moisture.

An installation of factory-lacquered hardboard in a bathroom showed no deterioration after eighteen months.

(*c*) *Concrete Floors.*—The purpose of the project is to determine the conditions necessary for concrete floors to be generally acceptable in domestic construction.

(i) *Physiological Investigations.*—The usual objection to concrete floors is that they are "cold and hard", but the real reason for these impressions is not clear. In an effort to understand the factors concerned, the physiological effects of the thermal and mechanical properties of floors are being studied. The method, adopted by several investigators, of measuring the "coldness" of floors by means of an artificial "foot", was considered unsatisfactory and it was decided to calculate, if possible, the "coldness" of floors of different materials from their thermal proporties. A mathematical analysis of the problem was made and a series of experiments carried out to check the validity of the argument and assumptions used. In these experiments the heat flow from the feet of human subjects to the floor was measured by means of suitably placed thermocouples. The tests were carried out on several persons in various degrees of activity from sitting to brisk walking. The results are now being analysed.

The effects of the mechanical properties of floors are being examined by measuring the instantaneous pressures at various parts of the sole of the foot during walking, and by determining the deceleration of the shin and the head during walking. An instrument for measuring the instantaneous pressures on the sole of the foot has been devised and records are being made of the pressures on different parts of the foot when walking at predetermined speeds over different types of floor. The pressure-time curves vary considerably with the person and the speed of walking, but no significant difference between the types of floor has so far been detected.

Although the study of the deceleration of the shin and the head during walking is still in an early stage, significant differences between floors have already been noted. It is interesting to note that decelerations of the head many times greater than those recorded in the literature have been observed.

(ii) *Experimental Floors.*—Observations of the behaviour of several experimental floors have continued. Sawdust-cement surfaces soon became pitted unless a large proportion of sand was included in the mix. Unless protected, floors based on bituminous binders were found unsatisfactory in houses, because the common practice of using oil or kerosene on mops caused staining and softening of the bitumen. The so-called "asphalt tile" appeared when wax-polished to be rather more slippery than other floor surfaces in common use.

The nine floors laid over concrete on ill-drained ground reported last year as showing no signs of deterioration due to dampness, still presented the same superficial appearance after fifteen months, although the underside of cork tiles laid with water-soluble adhesive had failed through rising damp.

(iii) *Indentation.*—Study of the effects of time, load, size of indenting sphere, thickness of specimen, &c., on the indenting constants of floor-surfacing materials was resumed. The results of the first set of experiments are now being analysed.

(iv) *Abrasion.*—A machine with constantly renewed loose abrasive was built to avoid defects inherent in machines dependent on fixed abrasives such as wheels and sandpaper.

(v) *Floor Coverings.*—Because of complaints that the linoleum now being used for hospital floors was markedly inferior to the pre-war material, a survey of floor-covering defects was made, by questionnaire, in co-operation with the Hospitals and Charities Board of Victoria. The replies show that there is no apparent difference between the pre-war and present-day products and that with both linoleum and rubber, most troubles can be traced to faulty laying and maintenance.

### 6. ACOUSTICS, INSULATING MATERIALS, AND BUILDING BOARDS.

(*a*) *Architectural Acoustics.*—The acoustic behaviour of rooms and halls is being studied both theoretically and experimentally. Theoretical investigation has shown that a three-dimensional model will provide a replica of the acoustical conditions in a room or hall if the sound frequencies used vary inversely to the dimensions.

The main difficulty in using a model is to provide bounding surfaces acoustically similar to those of the full-size room. This entails selecting a material whose acoustic impedance at model frequencies corresponds with that of the full-scale material at room frequencies, and the impedances of a range of materials, some of them specially prepared, have to be measured for this purpose.

The acoustic impedances of materials are being measured by the transmission-characteristic method under actual mounting conditions and at various angles of incidence. The impedances so obtained may be used to calculate sound-absorption coefficients. Sound absorption, although very important, is only one of the factors that affect the acoustic properties of a room or hall, and the relative importance of this and other factors is being studied.

(*b*) *Building Boards.*—Investigations into the relation between the properties of boards used as bases for external rendered finishes and the resistance of the rendered surfaces to weathering have been extended by erecting 10 more large-scale experimental panels. Results so far indicate that: (i) stucco on wire mesh without any base board was the most satisfactory construction, (ii) hessian scrim was the best jointing material for wood-wool boards, (iii) a mix of 1 cement: 1 lime: 8 sand by volume made the most satisfactory rendering.

To allow a choice to be made of suitable temperature and humidity conditions for tests on the stability of materials to atmospheric changes, meteorological records for Melbourne for an average year are being examined statistically.

(*c*) *Thermal Investigations.*—(i) *Conductivity.*—A large guarded hot-plate apparatus for specimens 48 inches square and a smaller one for specimens 12 inches square, both designed by the Division of Physics, are being installed for measuring the thermal conductivities of building materials.

(ii) *Sol-air Temperatures.*—It is necessary, in determining the thermal characteristics of buildings, to have quantitative data on the surface temperatures that are likely to occur. One way of determining these is by using the conception of the "sol-air" temperature, which is the temperature reached by a black body having infinite thermal resistance and zero thermal capacity. If certain assumptions are made, sol-air temperatures can be calculated, but to check the calculations experimentally a sol-air thermometer has been erected, and continuous records of the sol-air temperatures on horizontal and vertical surfaces are being made by an automatic recorder.

(iii) *Electrical Analogue.*—The construction of an electrical analogue for determining the thermal characteristics of buildings is nearly complete and it will soon be ready for calibration.

### 7. ORGANIC MATERIALS INVESTIGATIONS.

(*a*) *Bituminous Roofing Materials.*—Study of the suitability of bituminous membranes for flat roofs, which are widely used in Australia, has continued. Inspection of the roofs of a number of buildings in Sydney, Lithgow, and Canberra has provided further information on the performance of various types of roof covering. It has also stressed several aspects requiring laboratory investigation, notably the efficiency of the bond between layers of different types of membrane, the water-vapour permeability of membranes, the rot resistance of organic fibre felts, and the thermal characteristics of flat roof systems.

(i) *Laboratory Study of Roofing Components.*—Because built-up roofing membranes have a pronounced tendency to delaminate owing to the formation of blisters, tests are being made to determine the efficiency of the inter-layer bond of membranes of various kinds. It has been found that under short-term loading the bond between the layers of coated-roll roofing, which is commonly used in Australia, is significantly less than that between layers of saturated felts, which are generally used overseas. However, since, in practice, rupture by blistering is essentially a slow process, this conclusion should be accepted with reserve. Experiments are, therefore, being continued to test for differences in the time before failure under a range of static loads.

To investigate the possibility of microbiological decay of the felt fibres in organic fibre, felt bituminous membranes, samples were obtained from a leaking roof in Sydney believed to have been laid in 1930. The membrane, which was waterlogged and smelt sour, was desaturated and the organic fibre felt bases recovered, but neither mycological nor physical examination gave any evidence that the felts had suffered unduly by exposure.

Variation in the properties of one type of three-ply roll roofing was studied. Routine tests of the properties of common bituminous cements, dressings, and bitumens used in roof construction have been made to obtain data for exposure studies of various roofing systems.

(ii) *Exposure Tests of Membranes and Felts.*—Study of the weathering of felt specimens on exposure racks, and of the performance of the full-scale membranes laid on the three experimental huts at Highett, was continued. The membranes blistered more severely beneath black roof surfaces than beneath heat-reflecting surfaces. The thermal characteristics of a roof surface are believed to be important in the occurrence of membrane blisters, and in roof breakdown generally. Accordingly, an extensive programme of measurement of roof surface temperatures has been undertaken. Continuous records of the surface temperatures of fifteen surface treatments on a three-layer membrane of three-ply roofing, laid over a timber deck, are being made. The treatments found to be most effective in keeping the surface cool are, in order, whitewash (composed of quicklime and tallow), aluminium paint, and aluminium foil.

A bitumen-bonded aluminium foil membrane was laid on the roof of a cottage near Melbourne. Membranes of this type theoretically should obviate or minimize two of the factors believed to cause blistering, namely, water permeability and heat absorption. The state of this membrane after six months' exposure is unchanged.

(*b*) *Other Investigations on Bituminous Materials.*—At the request of the Victorian State Rivers and Water Supply Commission, consideration was given to the possibility of using a bituminous membrane to waterproof the temporary retaining wall of the new Eildon Dam. Small specimens of a six-layer hessian-reinforced bituminous membrane were prepared. These were tested for strength, and recommendations made for the laying of such membranes.

Experimental assistance was given to an intending manufacturer of an aluminium-foil cored bituminous damp-proof material.

(*c*) *Caulking Compounds.*—The conditions which joint sealing materials have to withstand are severe, and for this reason work was undertaken with the object of setting up criteria of efficiency for such products, and later of determining the factors governing the production of materials with given characteristics.

(i) *Correlation of Laboratory Studies and Exposure Testing.*—Experimental work on the relation between composition, short-term laboratory performance tests, and outdoor exposure tests of a variety of caulking materials is well advanced.

*Ad hoc* exposure testing of a variety of materials for jointing roof pavements has been continued. Rubber-bitumen seals and fatty acid pitch-bound seals were found very satisfactory.

(ii) *Rheological Properties of Mastics.*—The chief property of a jointing compound is its ability to withstand deformation without rupture. In addition, it must be easy to place in a joint and must not sag under its own weight. The measurement of these properties entails consideration of its rheological characteristics. An officer with experience in rheological problems has been appointed and sent overseas to acquire specialized experience.

### 8. DECORATION OF FIBROUS PLASTER.

When fibrous plaster is decorated with water paints, the paint film is prone to failure or disfigurement in several ways, such as occurrence of irregular purplish brown stains, often along the lines of flush jointing (evidence suggests that these stains are metallic sulphides); growth of mould; peeling; and occurrence of irregular dark areas having the appearance of a dampened surface. Work on the first two types of disfigurement is described below.

(*a*) *Sulphide Staining.*—There is now strong evidence that this strain is a metallic sulphide, but identification of the metallic radical is proving difficult. Sufficient iron is present in plaster and water paints to cause heavy sulphide stains when painted fibrous plaster is exposed to low concentrations of hydrogen sulphide, but the artificially produced stains differ in some respects from those occurring naturally; in particular, they fade rapidly, whereas the natural ones do not. Evidence has now been obtained from the behaviour of paint-plaster treatments in the experimental huts that sulphide stains are associated with cement sealer primers. It is thought likely that these stains are lead sulphide, the lead being derived from driers in the cement sealer primer. However, the problem cannot be fully resolved on present evidence. In one hut the naturally occurring stains have so far appeared over sealed areas on sheet manufactured from one brand of plaster only; in the other hut which was similarly treated no stains have appeared. Nor can all sulphide staining be due to the use of cement sealers or primers containing lead driers or pigments, for the use of such material is the exception rather than the rule, whereas stains are found to occur extensively and very frequently. Attempts have been made, so far without success, to solve this problem by x-ray and electron diffraction techniques.

Experiments are being carried out to explain, if possible, the mechanism of sulphide formation. It was observed in certain bayside localities that there was apparently sufficient hydrogen sulphide in the atmosphere to produce discolouration of exterior lead-based house paints. This suggested that atmospheric pollution might be the cause of staining of internal plaster decorative treatment also. Lead acetate test papers were installed in several dwellings but none have yielded positive results. In addition, laboratory tests have shown that hydrogen sulphide concentrations considerably in excess of those detectable by smell are necessary to produce noticeable staining.

Investigations of microbiological activity on protein-bound films in fibrous plaster have given more promising results. It has been found that organisms capable of liberating sulphides from protein media may be cultured from such surfaces; these, transferred to casein solutions, can produce rapid blackening when small quantities of ferrous sulphate are added. The organisms have not been identified although it has been shown, with the co-operation of the Chief Bacteriologist of the Melbourne and Metropolitan Board of Works, that they were proteolytic in type and not sulphate-reducing.

An experiment was made to find if these organisms were associated with sulphide staining. Sixty-six houses in Geelong were visited and 165 plaster samples taken from 38 " stained " and 28 " unstained " houses. However, the results were inconclusive and the experiment will be repeated with modified techniques.

(*b*) *Mould Growth.*—A noticeable rise in the incidence of mould growth on fibrous plaster in Victoria since the spring of 1949 has occurred, and detailed information has been collected on all cases reported. The growth of mould was earlier thought to be due to inadequate ventilation or insulation, but it now seems likely that this explanation is inadequate. The whole problem raises doubts as to the efficiency of fungicidal agents in water paints. In one of the experimental huts, in which " green " plaster was decorated with commercial water paints and in which the relative humidity was maintained between 80 and 90 per cent., mould growth appeared within three weeks. There are indications that even under less severe conditions such fungicidal properties as the paint may originally possess are fairly rapidly dissipated. On present evidence it is considered that painting with oil paints is the only safe procedure where mould risk is known to exist.

## XV. WOOL TEXTILES.

### 1. General.

During the past year, new arrangements have been made for wool textile research within the Organization. A new Wool Textile Research Laboratory is being organized in each of the three major textile centres, Melbourne, Sydney, and Geelong, and Officers-in-Charge have been appointed.

The major component of the Melbourne Laboratory is the Biochemistry Unit, which is staffed by officers formerly attached to the Biochemistry Section of the Organization's Division of Industrial Chemistry. The purpose of the research conducted in this unit during the next few years will be to contribute basic information relating to the composition of wool, to provide information which may lead to the development of entirely new processes in the wool industry, and to continue certain promising lines of fellmongering research. The staff of the Chemical Engineering group at Maribyrnong, who are investigating the solvent degreasing of wool, are associated with the Melbourne Laboratory.

In the Sydney Laboratory a Physics and Engineering Unit will study the physical principles underlying the behaviour of single and massed wool fibres and the operation of wool textile machinery. The Officer-in-Charge of this Laboratory is visiting textile research establishments and mills in the United States of America and the United Kingdom prior to the selection of staff and initiation of research. A group administered through the Sydney Laboratory will study the carbonizing of wool.

The Geelong Laboratory will be mainly concerned with investigations on existing wool textile processes, such as scouring, carding, combing, spinning, weaving, knitting, dyeing, and finishing, and on methods of mothproofing, shrinkproofing, and improving wear resistance.

Associated with the Geelong Laboratory is the Wool Textile Liaison Office, which will disseminate the results of Australian and overseas research to the wool textile industry and acquaint research workers in the Wool Textile Research Laboratories with the problems of industry. The Textile Liaison Officer is visiting the United Kingdom and Europe to familiarize himself with the most recent developments in textile research and the processing of textiles.

Other phases of wool research are being continued in the Divisions of Industrial Chemistry and Physics, which have special facilities and equipment not available in the Wool Textile Research Laboratories.

Location of officers engaged in research on wool textiles in several well separated C.S.I.R.O. laboratories will help the Organization to keep in touch with the wool textile industry in the different States, but it also makes it necessary for these officers to meet periodically to exchange views and experiences. The first Wool Textile Research Conference was held for this purpose at C.S.I.R.O. Head Office in November, 1949.

Another type of meeting, which took the form of an Exhibition and Discussion on the Testing of Textiles, was held at Geelong in May, 1950, mainly with the object of bringing modern methods of testing to the notice of members of the textile industry.

Two publications are issued from the Wool Textile Research Laboratories: the *Textile Newsletter*, which is prepared each month at Geelong for distribution to over 500 mills and laboratories, and the *Circular to Fellmongers*, which is released from the Melbourne Laboratory at approximately six-monthly intervals. The former brings information on overseas textile research and development to the notice of the Australian industry, while the latter conveys to fellmongers suggestions for improving processes, based on research in the Melbourne laboratory.

As in previous years, officers attached to the Geelong Laboratory have been accommodated in the Textile College of the Gordon Institute of Technology, and it is again desired to record appreciation of the assistance that the College is thereby contributing to the establishment of wool textile research in Australia. Most of the C.S.I.R.O. officers who have been located in the Institute expect to transfer to new Wool Textile Research Laboratories at Belmont, near Geelong, during 1950. Thanks are due also to the Department of Supply and Development for providing accommodation at Maribyrnong for pilot-plant studies of solvent degreasing.

The research projects on wool textiles are considered below in a sequence resembling that of the corresponding operations and processes of the wool industry. The work described under Section 2 was carried out in the Wool Textile Research Laboratories in Geelong and Sydney, that under Sections 3 and 12 in the Biochemistry Unit, and that under Section 5 at the Maribyrnong branch of the Wool Textile Research Laboratory, Melbourne. Section 4, 6 and 11 refer to research in progress in the Division of Industrial

Chemistry, Melbourne, Section 7 to the Wool Textile Research Laboratory, Sydney, Section 8 to the Division of Physics, Sydney, Sections 9, 10, and 13 to activities located at the Wool Textile Research Laboratory, Geelong.

### 2. BRANDING FLUIDS.

Field trials have been carried out on a branding fluid, L.B.E., which was previously developed in the laboratories of the Central Wool Committee, and the shorn wool has been subjected to scouring tests and made up into top, yarn, and felt. In the majority of experiments the brands have withstood weathering in the field and have been removed on scouring. Any traces of brand remaining in the wool after scouring disappeared during subsequent processing.

Work is in progress to improve still further the formula of the L.B.E. preparation which has now been released for general use. Experiments have been carried out to test the possibility of incorporating new pigments in the branding fluid, as several of those recommended are difficult to obtain and expensive. Using aqueous dispersions of the "Monolite" pigments, "Monastrol" blue and carbon black, it has been possible to eliminate the need for a ball-mill in mixing and also to cheapen the fluid considerably. Other work is concerned with reducing, and possibly eliminating, stearic acid from the preparation with a view to improving the scouring properties.

### 3. FELLMONGERING.

Research of direct interest to the fellmongering industry has been restricted during the past year to methods of recovering wool from skin pieces by complete digestion of the skin tissues. At least 12 per cent. of fellmongered wool is derived from this material.

The most favorable conditions for water digestion have been determined. A method of accelerating the process by pre-treatment with mould enzyme has been suggested, and it has been found that the same mould enzyme solution can be used repeatedly. It has been shown that thermal shrinkage of the skin pieces is essential for rapid digestion with mould enzyme, and also for water digestion if the pieces are from sweated skins. Pieces from skin treated with depilatory paint are digested in warm water only very slowly, even after deliming with acid and heat shrinking, but initial treatment of delimed painted pieces with mould enzyme gives a spectacular increase in the rate of digestion.

Immersion-digestion methods of recovering wool yield a product of good quality provided the water is changed frequently. The wool is rich in free fatty acids and may be partially scoured in soda ash solution without the addition of soap.

### 4. SCOURING.

Further studies in detergency were made, particularly in connexion with wool scouring. It was shown that the rate of detergency decreased during scouring, as dirt and wax accumulated in the washing solution and were re-deposited on the wool fibre. The relationship between the concentration of wax in the scour liquors and the extent to which this re-disposition occurs was studied quantitatively. This aspect of wool scouring is of considerable importance in wool wax recovery, since the proportion of the wool wax which can be recovered increases with the wax concentration attainable in the scour liquors. This will be one of the matters studied in work on the broad problem of wool wax recovery which has just been commenced. Laboratory work on a process for scouring wool at low temperatures has been completed and a large-scale test is being arranged.

### 5. SOLVENT DEGREASING.

All major units required for testing the solvent wool degreasing process at Maribyrnong have now been installed, reticulation is practically complete, and it is expected that the plant will be ready shortly for preliminary trials. A well-equipped workshop has been built near the pilot-plant to handle engineering work involved in the construction and maintenance of the plant.

Physical measurements on benzene solutions of wool wax have shown that refractive index may be employed for the rapid estimation of wax concentration in the solvent during the pilot-plant trials.

The possibility of removing suint from the fleece in addition to the wax is being studied by adding other solvents to the benzene and noting their effect on the solubility of suint.

### 6. WOOL WAX.

Present knowledge of the composition of wool wax is mainly of the alcohols and acids from which this ester wax is formed. Small amounts of paraffin and of free cholesterol have been found in the wax, but information on the esters forming the major part of the wax is lacking. An investigation has begun which aims to resolve the mixture of esters by physical means and to determine the compositions of these fractions.

In continuing the examination of the aliphatic alcohols of wool wax, a modified spinning-band distillation column was built, with which to fractionate these alcohols under very low pressure. The column has the equivalent of over 100 theoretical plates and a test showed that by the method of amplified distillation, it was possible with it to make a quantitative analysis of the alcohols from carnauba wax—a typical ester wax. The aliphatic alcohols from wool wax, however, have proved to be a more complex mixture and so far only a partial separation has been achieved.

The structural investigations of lanosterol were continued. The iodoacetates of this and the related agnosterol were prepared for X-ray examination, which, it is thought, will reveal the broad structural features of the molecules. The alkaline hydrolysis of wool wax is an important step in the production of wool wax alcohols and of cholesterol, and the study of the factors concerned in this operation was continued.

### 7. CARBONIZING.

The carbonizing process was developed about 1870, primarily for the purpose of removing the excessive amount of clover burr which contaminated the Australian wool clip. Sulphuric acid is generally employed in this process, under conditions which cause charring of the vegetable matter but no serious damage to the wool. Aluminium chloride and hydrochloric acid are also used for particular types of fabric. The effect of carbonizing agents on the loss in strength of wool and also of cellulose, the main constituent of burrs, will receive early attention, and a ballistic method of measuring the strength of cotton and woollen fabrics and fibres is being examined.

The possibility is also being investigated of using high-frequency dielectric heating for concentrating the sulphuric acid in burry wool, instead of evaporating the water from the acid by convection and conduction as at present.

### 8. PHYSICAL PROPERTIES OF FIBRES.

A knowledge of the physical properties of single wool fibres is fundamental to the understanding of such matters as the criteria which determine the quality of wool, the processes of spinning and weaving, and the properties of wool and textiles. It has been the aim of the Wool Section of the Division of Physics to determine the physical properties of wool fibres and to develop their inter-relationships, in the attempt to produce a coherent explanation of the behaviour of wool.

(*a*) *The Frictional Properties of Single Wool Fibres.*—The dependence of these properties on the humidity of the surrounding atmosphere is still being investigated. The data obtained will later be used in a study of yarn properties.

The anti-felting effect produced by the deposition of certain polymers on wool fabrics has been shown to be due to a gluing together of the fibres by these polymers. If the polymers are deposited on loose fibres, the difference between the rootward and tipward coefficients of friction on the single fibres is not significantly reduced, and no anti-felting effect is produced in fabrics made from these treated fibres.

(*b*) *Elastic Properties of Single Wool Fibres and of Other Forms of Keratin.*—A comprehensive study of these properties is now in hand. The problem is being attacked from several angles, initial emphasis being placed on the measurement of elastic constants by ultrasonic methods, and on the contraction of keratin fibres, under certain conditions, to less than their original unstressed length.

(*c*) *Yarn Properties.*—A start has been made in the study of the relationship of yarn properties to the properties of individual fibres and to the geometrical structure of the yarn.

(*d*) *Measurement of Fibre Length.*—The work on the electrostatic fibre-length meter, mentioned in the last Report, has been discontinued, as the voltage required was too high for the development of a useful instrument, although the method was satisfactory in principle.

### 9. YARN QUALITY.

Research is in progress on the evaluation of factors affecting yarn quality. After examination of available methods, a satisfactory procedure has been developed for measuring various characteristics of fine worsted yarns. A Turl-Boyd evenness recorder has been installed for use in this work and a suitable method for expressing irregularity has now been adopted.

In collaboration with industry, a comparison is being made of yarns produced from the same tops by different methods including the American high-draft, Bradford, and French systems.

Irregularities in yarn-twist, which result from variations in the number of fibres in cross-section, have been shown to be one of the major factors affecting the appearance of knitted and woven fabrics. The number of breaks occurring when yarn is wound under constant tension is not necessarily related to the mean breaking-strength, as determined on a pendulum-tester. This means that breaking-strength measurements on yarn do not necessarily reflect the performance during subsequent processing such as weaving and knitting.

### 10. CHEMICAL MODIFICATION OF WOOL.

(*a*) *Application of Resins to Wool.*—Research has continued on the treatment of wool with synthetic resins. A new method of shrinkproofing has been devised in which surface deposits of certain polymers, prepared from waste nylon, are applied to the wool. As little as 4 per cent. of resin on the weight of wool is sufficient to shrinkproof it and, at the same time, increase its resistance to abrasion by approximately 75 per cent. Attempts are being made to develop an industrial treatment based on this method.

Studies on the formation of polymers in wool have been continued and further information has been obtained on the mechanism of the reaction between reduced wool and vinyl monomers, reported last year. From *in vitro* experiments, it has been found that cysteine and related compounds can form powerful polymerization catalysts in the presence of traces of oxidizing agents. In reduced wool, therefore, the combined cysteine probably reacts with oxidizing agents already present in the fibre and so can catalyse polymerization. In support of this view, it was found that polymer forms only in the tip of a staple, where oxidation products are normally present, and not in the base. However, if the base is treated with a weak oxidizing agent, such as hydrogen peroxide, there is no difficulty in subsequently synthesizing polymers in this portion of the staple also.

The absorption of methacrylamide by wool has been studied in detail, as this compound forms polymers capable of being cross-linked to the side-chains of the wool. It was found that it is absorbed slowly by wool and only in small amounts. However, once some polymer has been formed in the fibre, its affinity for monomer is greatly increased, thus explaining the fact that the amount of polymer formed greatly exceeds the maximum absorption of the monomer by wool.

A method for forming internal deposits of resins in wool from water-insoluble monomers is being investigated. Such compounds, which are usually polymerized from aqueous emulsions, tend to form polymers on the surface of the fibres. The present method uses aqueous methyl alcohol solutions of the monomers with ferrous iron and hydrogen peroxide as catalysts, and it has been found that substantial amounts of resins can be formed within the fibres, which are greatly strengthened by the treatment.

(*b*) *Action of Shrinkproofing Reagents on Wool.*—A study is being made of the chemical mechanisms of shrinkproofing wool with reagents such as alcoholic alkali, sulphuryl chloride, and chlorine. Wool rendered shrinkproof with the above reagents has been found to yield increased amounts of pyruvic acid on hydrolysis. This indicates a probable loss of sulphur from Fraction C + D of the cystine during the shrinkproofing treatment. Experiments at present in progress indicate that hydrolysis of main-chain peptide linkages also occurs with alcoholic alkali.

(*c*) *Cross-linking Reactions.*—The action of mercuric acetate on wool is being investigated. This compound was thought to cross-link the protein chains in wool through acidic and basic side-chains; from the experiments now in progress, it appears that additional groups are involved in the reaction. Samples of the treated wool were tested by the Division of Entomology and found to be moth-resistant. The method would, however, be too costly for industrial use.

The action of other metallic compounds is being studied, and it has been found that their uptake by wool is considerably less than that of mercuric acetate. None of the treated samples has shown the moth-resistance displayed by wool treated with mercuric acetate. Some have shown increased resistance to abrasion.

### 11. PROTEIN STRUCTURE.

Investigations of the histology of wool fibre and hair and the structures of keratin and related proteins were continued by the Chemical Physics Section of the Division of Industrial Chemistry.

(*a*) *Wool Structure.*—Particular attention has been paid to the cuticle of the fibre, which is now known to consist of at least three components. Of these, the epicuticle, the thin membrane covering the whole of the external scaly surface, has been shown to consist of a very resistant protein-like substance not readily attacked by most chemical reagents and therefore forming an effective barrier for protecting the more vulnerable portions of the fibre. The elementary composition of epicuticle isolated from the fibre is being determined. The intact epicuticle limits the penetration of water, dyes, and other chemicals used in finishing textiles; attention is being given to the facilitating of dyeing and "wetting-out" by the uniform removal or perforation of the epicuticle. Damage to the epicuticle during manufacturing operations can be determined by electron-microscopical examination. It has been established that the initial damage occurs at the scale edges and subsequently on the smoother surface.

Further electron-microscopical studies of the fibrillar and macro-molecular structure of the cortex of the wool, and of the analogous fibrillar components of other keratins, have been made. Certain structural details not well developed in wool are expected to be more obvious in the corresponding features of other fibrous proteins; partly for this reason a study has been made of muscle and of spermatozoa, which, although of quite different function from hair, show structural similarity at the macromolecular level. Many new histological details have been discovered. The investigation is being continued on account of its importance in problems related to this work.

(*b*) *Structure and Synthesis of Fibrous Proteins.*—Infra-red spectroscopic and x-ray crystallographic methods are being used to study the molecular structure of amino acids, lower peptides, synthetic polypeptides, and natural fibrous proteins. Infra-red absorption is being used to characterize and establish the orientation of certain molecular groups in these compounds; complete structure analysis of certain amino acids has given valuable information on their molecular arrangement.

The genesis of the fibrous arrangement of the molecules from the non-fibrous protein precursor has been the subject of a theoretical study, which indicates that purely physico-chemical forces may, under certain conditions, lead to linear aggregation, rather than to two- or three-dimensional crystallization. Experimental tests of this theory are in hand.

The manner in which the protein is formed and modified within the hair follicle is being studied by means of microscopical and macrochemical techniques and by x-ray microradiography.

### 12. PROTEIN CHEMISTRY.

(*a*) *Wool Fibre Investigations.*—Wool has usually been regarded as a single protein belonging to the group known as keratins, but recent work suggests that it may be a complex association of a number of slightly different keratins. All proteins can be regarded as long chain molecules formed by linking together some 20 different amino acids, but the proportions of these amino acids vary considerably from one protein to another. Not only do the proportions of the different amino acids vary, however, but also the order in which they occur. Thus, considering three amino acids A, B, and C, a chain of only three such units could be represented by any of the following: ABC, ACB, BAC, BCA, CAB, or CBA. The great difficulty of determining the correct arrangement of the 20 amino acids occurring in wool keratins is one of the major problems confronting those engaged in research on wool chemistry. Another will be to identify and locate the cross-linkages which serve to convert the chains of amino acids into a three-dimensional lattice. The molecular structure of keratin is being intensively studied, for this largely determines the physical properties of wool and its behaviour during processing, for example, the conditions under which wool is damaged during soap-soda scouring and during carbonizing with sulphuric acid, the reactivity with shrinkproofing agents, the affinity for moisture, the action of lubricating oils during processing, and the penetration and uptake of dyestuffs.

In view of the basic resemblance between all proteins, information of value in determining the chemical structure of wool keratin will emerge from studies of other proteins in general, and techniques which will be employed ultimately in the study of wool are being developed and tested against proteins which are more convenient to use and have been more completely characterized by other workers. Thus, wool cannot be dissolved or dispersed in liquids for measuring physical properties without first partially degrading it, but other proteins, such as the red blood pigment, haemoglobin, and blood serum albumin are readily soluble in water and have, therefore, been used to standardize physical equipment for subsequent application in determining the size and shape of protein derivatives from wool keratin. Similarly the protein myoglobin, prepared from horse heart muscle, having approximately 144 amino acids in its single chain, and insulin, the sub-units of which contain 4 chains each of 20-25 amino acids, are being used in preference to wool keratin to develop new methods of identifying the end components in the amino-acid chains.

A method recently reported in the literature for removing a particular amino acid from proteins has been shown to exert a similar effect on wool; and this procedure, used in conjunction with methods of identifying the exposed amino acids, will contribute further knowledge concerning the arrangement of amino acids in the chains. For the end-group identification investigations, heterocyclic derivatives of amino acids have been prepared and characterized, for comparison with similar compounds which may be formed with terminal amino acids in proteins and subsequently split off the chains. Research on methods of peptide synthesis has also been continued.

(*b*) *Wool Root Investigations.*—Research on wool roots is being extended in order to learn more about the way in which the constituent amino acids of wool are built up into keratin. Specific decarboxylases are being used in the Warburg manometric apparatus to estimate the amino acid concentrations more accurately than was previously possible. It has been found that some of the enzyme systems concerned in the metabolism of the cells of the wool roots cannot be removed from the cellular material by extraction, and it is necessary to study them in cell suspensions.

(*c*) *Enzyme Investigations.*—Methods of fractionation, which it is hoped to apply to dispersions of wool, are being developed for the separation of closely-related mould enzyme proteins from one another in mixtures. Already the application of one such method, involving the use of ethanol at a low temperature, has led to purification of a protein-splitting mould enzyme from a complex mixture and its precipitation in a crystalline form. Further work on the fractionation of the mould enzyme mixture, using a zinc salt method developed in the United States of America for the fractionation of blood plasma proteins, shows promise of separating the constituents with much lower ethanol concentrations than were previously found to be necessary. This will decrease the likelihood of the proteins being altered during separation.

### 13. WOOL TEXTILE LIAISON.

Besides publishing the *Textile Newsletter*, the Wool Textile Liaison Office at Geelong provides a reference service for handling technical inquiries. A comprehensive textile reference library is being established and is already well supplied with current and back numbers of periodicals and with reference books.

Active representation has been maintained on textile committees of the Standards Association of Australia, and contacts have been established with similar groups overseas.

## XVI. FLAX.

### 1. GENERAL.

There is general agreement as to the desirability of retaining an efficient flax industry in Australia, but some doubt as to whether this can best be done on a Governmental basis or by private enterprise. With the exception of small quantities of cotton, flax is the only vegetable fibre produced on a commercial scale in this country, and as the raw material best suited for tarpaulins, fire-hoses and high-quality threads, it is an important peace-time commodity and an essential war material. The delay in effecting definite arrangements for the continuance of the industry has resulted in a considerable falling off of the acreage being sown to flax, but there is now a strong body of opinion that this decline is temporary only. The establishment of a successful industry, however, will depend largely on continued research into the problems—many of them unique—associated with the production of high-quality fibre from Australian-grown flax plants. It was for this purpose that the C.S.I.R.O. Flax Research Laboratory at Highett, Victoria, was set up.

The activities of this Laboratory embrace a wide field of research, both fundamental and applied, and extending from agricultural problems to investigations of manufacturing methods. Through the helpful co-operation of the Flax Production Committee (Department of Commerce and Agriculture), it has been possible to extend the more promising investigations to a commercial scale at one or other of the Committee's flax mills. The Laboratory is also indebted to the Flax Production Committee for a number of items of equipment and machinery which have proved of great value.

### 2. AGRICULTURAL INVESTIGATIONS.

Close liaison between the Departments of Agriculture in Victoria and South Australia and the Flax Research Laboratory has enabled various agricultural field trials to be carried through from the growing of the straw to the spinning and testing of yarn from the fibre. A pleasing feature of these trials has been the good yields of high-grade fibre obtained from some of the new rust-resistant varieties bred in Victoria. The bulking up of the more promising of these would appear well worth while, as the overseas varieties available in this country all suffer severely from rust infection.

### 3. PROCESSING.

(*a*) *Water Retting.*—A substantial contribution to the knowledge of water retting was made last year when it was shown that the water retting of Australian flax could be greatly improved by the introduction of certain overseas types of bacteria not commonly present in Australian straw. When the ret was inoculated with these special bacteria, not only was retting accelerated, but it produced a fibre of much higher quality. During the present year, efforts have been made to devise methods of carrying on the retting bacteria from ret to ret so as to avoid the necessity of inoculating each ret separately, this being impracticable on a commercial scale.

One of the most promising methods of doing this is by means of the aerated ret. This is carried out in tanks in the normal way except that air is bubbled through the liquor during the process. The aeration permits the acidity of the liquor to be controlled so that the same liquor and, it is hoped, the same bacteria can be used repeatedly. This method of retting also simplifies the effluent disposal problem and conserves water.

Following successful laboratory tests, the aerated method of retting was recently tried on a commercial scale at one of the flax mills. A series of nineteen rets was completed in the original liquor, with the addition of a small amount of fresh water each time to make up for that removed with the wet straw. Generally speaking, the results were very gratifying and proved the feasibility of this technique.

Another method of retting, which has so far been tried on a laboratory scale only, but which may well provide an alternative method of preserving the retting bacteria, is to inoculate normal anaerobic rets with retting effluent from a previous ret that has been aerated at about 36° C. until its pH rose to a value of 7.5. Unless treated in this way, the effluent appears to have little value as an inoculum.

The systematic study of the bacteria associated with water retting has been continued. There is a wide range of types of bacteria present during the process and, although all are not active retting agents, there is reason to believe that the presence of some of the non-retting types may be essential to the success of the process. This study is of a fundamental nature but has already proved to be of considerable practical significance.

(*b*) *Scutching.*—Much useful information has been obtained from a study of the performance of the scutching machines at the six water-retting mills in Victoria. In this test, one-ton samples of blended straw were processed on each machine. Variations from 19 to 24 per cent. in fibre yield were obtained on different machines. Wide differences were also found in the times required to scutch similar lots of straw; some teams took four times as long as others. There were also wide variations in the tow yield at different mills, suggesting that in some cases the tow was being blown away with the shives and burnt. A full report on the investigations has been made to the Flax Production Committee.

A number of mechanical modifications intended to improve the efficiency of the standard scutching machine are being investigated. At present these modifications are directed towards improving the existing machine as economically as possible rather than radically changing its design.

A study is being made of the conditioning of flax straw, the moisture content of which needs to be increased if scutching is to be carried out satisfactorily during the summer months. This problem is of considerable importance.

(*c*) *Preparing and Spinning.*—The spinning of fibre from a number of agricultural and processing trials has been carried out in connexion with the evaluation of the fibre. The reproducibility of test results has been demonstrated. Investigations of spinning technique include a study of the effect of twist, spinning frame draft, and drawing frame drafts and doublings. On the mechanical side, mention should be made of the work being carried out in co-operation with the Division of Forest Products to find a satisfactory Australian timber to replace imported timber for pressing rollers. Various methods of fabricating such rollers are also being investigated.

(*d*) *Boiling and Bleaching.*—Preparations have been completed for routine kier boiling of the yarns spun at the Laboratory and for carrying out investigations of methods and techniques for boiling and bleaching yarns. This work includes the photoelectric measurement of colour.

### 4. CHEMICAL PROPERTIES OF FLAX.

(*a*) *Plant Analyses.*—Chemical analyses of green-leaf samples from a large number of flax crops, to determine the levels of major and minor nutrient elements necessary for the growth of high-quality flax, have so far covered nitrogen, phosphorus, and calcium.

(*b*) *Fibre Analyses.*—Study of the chemistry of flax fibre is one of the more fundamental of the Laboratory's research activities, but is also necessary for an appreciation of processing and manufacturing problems.

The chemical composition of flax fibre of various grades is indicative of the efficiency of the processing treatments which it has already undergone, and also provides a basis for the rational investigation of subsequent treatments, such as boiling and bleaching. Constituents of the fibre which appear to have a major effect on its properties are the hemicellulose and the water-soluble uronic acids.

### 5. Physical Properties of Flax.

(*a*) *Flax Anatomy.*—Basic information was obtained on the development of the fibre in the stem of the flax plant. This is of particular interest in connexion with agricultural field trials of the time of harvesting. The effect on the development of the fibre of using growth-substances was also studied. It would appear that these tend to produce a coarser fibre, probably of lower grade.

A comparison of the anatomical structure of Australian and overseas flax has been completed. This indicates that there is no significant physical difference between fibre from the same type of straw grown in Australia and, say, Belgium, and suggests that the problem of producing Australian fibre of comparable grade is one of processing.

(*b*) *Fibre Properties.*—The possibility of being able to assess spinning performance from fibre properties was given further consideration. A study of the splitting of fibre bundles during hackling was made as part of the investigation of the effect of fineness on spinning performance.

(*c*) *Yarn and Cloth Properties.*—Methods of testing as applied to flax yarns and cloth are being investigated. With the use of a specially designed cabinet in which temperature and humidity can be closely controlled, equilibrium moisture-content curves are being determined for Australian flax canvasses, and also the relationship between moisture content breaking load over a wide range of conditions.

## XVII. INDUSTRIAL CHEMISTRY.

### 1. General.

Although a number of the Organization's Divisions and Sections undertake chemical investigations in connexion with their own specific fields of study, its main centre for applied chemical research is the Division of Industrial Chemistry with its laboratories at Fishermen's Bend, Victoria. In addition to carrying on its own research programme this Division, with its specialized personnel and equipment, renders assistance both to other research groups within the Organization and to industry. Its work, except the fuel utilization investigations (*see* Chapter XIX., Section 4), is described in this Chapter.

Chemical research relating to problems of various secondary industries is also undertaken by the Division of Forest Products (Chapter XIII.), the Division of Building Research (Chapter XIV.), the Division of Food Preservation and Transport (Chapter XII.), the Wool Textile Research Laboratories (Chapter XV.), and on primary and secondary metallurgy by the Physical Metallurgy Section (Chapter XX.), the Ore-dressing Laboratory (Chapter XVIII.), and the Division of Tribophysics (Chapter XXI.).

*Division of Industrial Chemistry.*—Of the ten years that the Division has been in existence, the first five were devoted to work generally of a short-term nature and selected with the object of making the greatest possible contribution to the war effort. Since the war ended, however, the policy has been to concentrate as far as possible on long-term work of wide significance or national importance.

Among research projects of this type might be cited the work on wool, which comprises studies on the ultimate chemical and physical constitution of wool, on the scouring of wool, and on wool wax. The last-named is related to another major project in which it is sought to recover and refine waxes of local origin so that the Commonwealth may be less dependent on dollar-consuming imports. Much promise is shown by sugar-cane wax, which could be recovered in considerable quantity from waste materials of the sugar mills.

A project of some magnitude has been commenced in connexion with the utilization of brown coal. This will provide the basic data for an integrated utilization programme if it should become advisable to produce liquid fuels and organic chemicals from the extensive low-rank coals of Australia. The results will also be of value to the gas-making industry.

To assist the ceramic industry, a survey and evaluation of some of its most important raw materials is being made in collaboration with the University of Melbourne and the Mines Departments of several States. The first report, dealing with the clay resources of South Australia, is now being prepared. An extensive research aimed at improving the performance of refractories, particularly for the gas and cement industries, is well under way. It is emphasized that research work of this type, though it may benefit from overseas experience, is essentially a question of finding how to use Australian raw materials to best advantage. If Australia has no ball clays identical with those of Devon and Dorset, she must learn how to make first-class goods from what is available; she must look for the intrinsic virtues of her own materials, not merely for differences from those used elsewhere.

Reference has been made in earlier reports to work on such minerals as zircon, rutile, and monazite, which occur in very big tonnages in the beach sands of New South Wales and Queensland. During the war there was a ready market for several of these minerals, but new uses must be found if satisfactory exploitation is to be maintained in peacetime. The Division has worked on these minerals since the time of its inception; they and the metals titanium and zirconium, which are derived from them, are now the subject of a huge amount of research overseas, though this is along different lines from that in progress in Melbourne.

Development of methods of recovery of uranium from South Australian ores continues to be a major project and satisfactory progress has been made.

Some of the chemicals, e.g. the essential oils, occurring in Australia's indigenous flora have been the subject of extensive research work in University and other laboratories, but until recently little attention has been paid to alkaloids. Investigations in conjunction with the Division of Plant Industry and several University Departments are making good this deficiency, and results of considerable importance in organic chemistry have already been obtained. It is hoped also that, from time to time, alkaloids of value in medicine or veterinary science will be discovered. In conjunction with the Division of Animal Health and Production, the alkaloids of certain grasses poisonous to stock are being studied.

Another long-term project is the application of surface chemistry to the study of the flotation of minerals. In 1947 the leader of the Section responsible for this work resigned to undertake research at the Royal Institution, but has recently returned as leader of the Physical Chemistry Section.

One of the Division's most important projects, inaugurated soon after its establishment, has been a study of the principles underlying the processes used by fellmongers to recover wool from sheepskins. From this project has arisen research on the genesis and growth of the wool fibre. These and other projects were undertaken in the Biochemistry Section. This Section had reached a stage of development where, during the year, it was considered desirable that it should leave the Division to serve as a nucleus for the group of Wool Textile Laboratories being established in Melbourne, Geelong, and Sydney respectively. Its leader has been appointed Senior Officer-in-Charge of the group.

The Division has continued to provide facilities for guest workers from other institutions in Australia, including other Divisions and Sections of C.S.I.R.O. Its chemical engineering equipment has been used freely by industry, which has usually provided the personnel for work undertaken on its behalf. There is a steady stream of visitors to the Division to inspect its equipment or to discuss industrial or academic problems with the staff, and there have been a number of well-attended visits by technical and scientific societies. Liaison with industry has been maintained in this way, and by visits to industrial concerns by members of the staff. There is a similar close connexion with the universities, resulting in extensive use of the Division's facilities for pure and applied research.

### 2. Minerals Utilization.

Naturally-occurring minerals may be of value to industry either *per se*—examples are mica, asbestos, and natural abrasives—or as sources of metals and non-metallic derivatives. The Minerals Utilization Section was set up to investigate the properties of the diverse products obtainable from such minerals, with the dual object of promoting and widening industrial use of Australian mineral reserves, and of contributing to fundamental knowledge of inorganic chemistry. Improvements to the usual methods for processing minerals are studied concurrently with procedures designed to create new uses for the derivatives. Special attention has been given minerals containing the rarer elements, since Australia is relatively well endowed with some of these minerals, and the use of their derivatives in industrial processes is increasing.

(*a*) *Monazite.*—As a component of the heavy mineral sands of the eastern Australian littorals and of certain stanniferous alluvials, monazite offers much scope for applied chemical research by reason of its varied rare earth and thorium content, and their very diverse industrial applications. Work has been undertaken to improve the chemical processing of this mineral to give high overall recovery of the constituents. High-temperature chlorination of monazite was explored as a means of producing phosphorus-free dry chlorides of the rare earth metals of the cerium group, with concurrent isolation of thorium chloride. This process has certain advantages over the conventional methods for treating the mineral. An improved form of the sulphuric acid decomposition process was developed and a comparison made of the quality and variety of the products obtainable by each of these methods. The isolation of thorium compounds and their purification from associated elements received particular attention, and studies on the chemistry of various complex rare earth salts and on the double fluorides of thorium were continued.

(*b*) *Rutile.*—Studies on titanium compounds derived from the mineral rutile, via titanium tetrachloride, have been chiefly directed to titanium nitride, and its use as the essential component of a "hard metal", analogous to that produced from tungsten carbide, for cutting and grinding tools. A satisfactory method for synthesizing the uncontaminated nitride was developed and many metallic bonding compositions suitable for making sintered compacts of the nitride were examined. A very promising "hard metal" product has been developed which warrants further testing.

(*c*) *Zircon.*—As the main component of the abundant mineral sands of the beaches of southern Queensland and northern New South Wales, and as the essential ore of the metal zirconium, this mineral has figured prominently in the research programme. Long-term studies on the separation and purification of the closely associated hafnium and zirconium by the lower anhydrous chloride method were continued. Special attention was paid to the quantitative estimation of hafnium in the presence of zirconium; the use of a radio-isotope indicator facilitated this work. Some preliminary tests were made on a modified process for preparing ductile zirconium metal.

(*d*) *Uranium Ores.*—Considerable progress has been made in developing a selective solvent process for extracting uranium compounds from low-grade titaniferous ores.

(*e*) *Manganese Oxides.*—The X-ray diffraction study of the structure of the various natural and synthetic oxides of manganese, which was originally aimed at correlating their structure with their performance in dry cells, has been extended to include other substances. A detailed structure analysis of the mineral cryptomelane was undertaken and a comparison made with related materials.

(*f*) *Graphite.*—Work on the colloidal dispersion of high-purity South Australian graphite has been continued. Products obtained from this material were tested as lubricants by the Division of Tribophysics and were shown to be equal in quality to the best imported colloidal graphite lubricants. Other investigations have established that the anhydrous chlorides of iron and aluminium, both of which occur in the products of industrial chlorination of bauxite, may be separated by heating the chloride mixture with graphite. Samples of processed South Australian graphite have been specially ground and prepared for testing by the lead pencil industry. Further fundamental studies on graphite have included an examination of the chemical and physical methods of classifying graphites, the kinetics of the formation of graphite-ferric chloride complexes, and an examination of the structure of graphite oxide which was made with the co-operation of the Chemical Physics Section.

### 3. Cement and Ceramics.

Although all the investigations of the Cement and Ceramics Section are of a long-term character, it has been possible to provide some practical assistance as well as advice to industry. Active support and financial assistance have been given by the Cement and Concrete Association of Australia to the Section's cement investigations, and by the National Gas Association to the investigations of gas-retort refractories.

(*a*) *Cement-Aggregate Reaction.*—This investigation, which is related to a type of cracking and consequent deterioration which occasionally appears in concrete structures, continues to receive attention. Much of the current work is concerned with the mechanism of the reaction between certain types of aggregate and the cement in mortar. It has been shown that, within limits, the expansion and degree of disintegration of mortar is increased as the size of particles of reactive aggregate is decreased. When, however, the size of the particles is sufficiently small to allow them to pass through a 300-mesh sieve, the mortar does not expand. The addition of such particles to an otherwise reactive cement-aggregate combination lowers its expansion. This may in part be due to the pozzolanic properties shown by many finely ground reactive aggregates.

Further tests for reactivity of aggregates to be used in important concrete structures have been made for various public bodies. Most of these aggregates proved to be non-reactive, but some showed dangerous reactivity and have been rejected as the result of these tests.

(*b*) *Pozzolanas.*—These are materials, either natural or heat-treated, which possess cementitious properties when finely ground and mixed with lime. An investigation of the properties and behaviour of possible Australian pozzolanic materials has recently been initiated. Under certain circumstances pozzolanas are used overseas to improve the durability of concrete and to decrease liability to cement-aggregate reaction.

(*c*) *Effect of Surface-active Agents in Cement and Concrete.*—This investigation at present largely consists of a study of entrainment of air in cement pastes and mortars. The effect of various types of surface-active agents is being examined. (*See* also Chapter XIV., Section 3 (*a*).)

(*d*) *Cement Clinker Investigations.* — Further clinkers of carefully controlled composition were made in the laboratory, and the properties of cements prepared from them were examined.

In the study of clinkers the separation of some liquid (glass) from the solid (crystalline) phases has been achieved. Further separations are being made in order to obtain sufficient glass for more detailed study.

Radioactive tracers are being used in an attempt to obtain more information about the constitution of the components of cement clinker.

(*e*) *Refractories Investigations.*—The study of the after-expansion/contraction characteristics of Australian gas-works refractories has been completed. The results are being circulated to the suppliers and users concerned and an extended and critical discussion is being prepared for publication. Some products showed excessive after-contraction, the reasons for which have been investigated.

Further attention has been given to the factors influencing the durability of cement-kiln linings. The stress distribution in such linings, as produced, for example, during cooling, has been studied mathematically and by the building of model structures.

(*f*) *Clay Investigations.*—A preliminary account of the mineralogical and ceramic characteristics of South Australian clays has been prepared for publication. A similar study of Western Australian clays is in hand. A number of requests for the examination of clays from various sources has been met where potential commercial value appeared to warrant the investigations.

The rheological and other colloidal properties of clays have received further attention; in connexion with this work, considerable data have been accumulated on the phosphatization of clay-minerals and the use of phosphates as deflocculants.

(*g*) *Silica Investigations.*—A study of certain Australian sources of silica has commenced and special notice is being taken of microcrystalline types of possible value for the manufacture of pottery. A fundamental investigation of the effects of heat on certain varieties of microcrystalline silica is nearing completion.

(*h*) *Whiteware Investigations.*—The investigation of the processes operative during the maturing of whiteware bodies has been extended and some interesting phenomena have been noted. It is hoped that this investigation may assist in the selection of unfamiliar materials for ceramic purposes.

(*i*) *Saggar Investigations.*—Saggars constitute an important and expensive item in many branches of the ceramic industry. Saggar-compositions which are giving excellent results under service conditions have been developed from South Australian and other materials; full details will be published if warranted by further plant trials.

### 4. FOUNDRY SANDS.

The Foundry Sands Section carries out its work in close contact with the foundry industry and provides an advisory service dealing with all types of foundry problems; the strong demand for this service has been maintained.

Surveys of the known foundry sand deposits of all the mainland States have now been published, or are in course of publication; the testing of further potentially valuable deposits is continuing. A survey of Tasmania is being undertaken, and sampling of sand deposits in that State will begin shortly.

Developmental work on the use of materials produced in Australia to replace linseed oil as binding material for baked foundry cores has been carried on. Equipment has been designed and constructed for precise measurements of the properties of cores.

Certain Australian clays have been tested as substitutes for the American bentonites used as binders in synthetic moulding sands. Some of these clays show promise of successful application.

### 5. PHYSICAL CHEMISTRY.

The Physical Chemistry Section is concerned with the application to industrial processes of the principles of surface chemistry. Work has continued on two processes, the flotation of minerals and detergency, in both of which the properties of surfaces are dominant factors.

(*a*) *Flotation Investigations.*—Work has been continued on a number of aspects of the flotation of minerals with the object of obtaining a clearer understanding of the mechanism of the process. Details of this work appear in Chapter XVIII., Section 4.

(*b*) *Detergency.*—The scouring of wool has been further studied, and the general trend of this work is described in Chapter XV., Section 4.

A number of inquiries from industry and from other research groups within the Organization on subjects relating to flotation, detergency, and surface-active agents have been answered.

### 6. CHEMICAL PHYSICS.

New temporary accommodation has been provided for the X-ray crystallographic, protein structure, and glass-working laboratories, and this has lessened the overcrowding in some parts of the Chemical Physics Section. An officer, to be located eventually in the Chemistry Department, University of Western Australia, has been appointed for work on vacuum ultraviolet spectroscopy; the apparatus required for this project is being constructed in the Instrument Laboratory. Five guest workers from other scientific institutions have worked in the Section's laboratories for various periods, two of them for the whole of the year.

(*a*) *Protein Structure Studies.*—Fundamental and applied studies related to the Organization's wool research programme have been continued. The work is described in detail in Chapter XV., Section 11.

(*b*) *Development of Chemico-physical Techniques.*—Since the work of this Section depends largely on the use of modern physical methods, it is necessary to extend the capabilities of existing methods and develop new techniques where they are judged to be important.

(i) *X-ray Microscopy.*—This technique promises to be of considerable importance in biological studies, since, by the use of different X-ray wavelengths, it should be possible to determine the distribution of the various chemical elements throughout any suitable specimen. Some progress towards the development of a high-resolution X-ray microscope has been made;

in particular, a suitable choice of wavelengths has been shown to lead to a more readily constructed instrument.

(ii) *Mass Spectroscopy.*—An apparatus to allow automatic recording of appearance-potential curves for positive-ion fragments has been developed for use in conjunction with the mass spectrometer. Data on bond-dissociation energies, necessary for an understanding of chemical reactions, have been obtained with this equipment.

(iii) *X-ray Diffraction.*—A 10-kW. gyrating-anode X-ray generator has been designed and its construction is almost complete. It will greatly facilitate the study of the macromolecular structure of natural proteins, including those occurring in wool.

(iv) *Electron Diffraction.*—The use of a high-resolution electron diffraction camera developed in this Section has provided information which it would be impossible to obtain with most other cameras in use throughout the world. To take full advantage of some of these findings, it has been necessary to design a second instrument capable of higher resolution still. This is now under construction.

(v) *Spectroscopy.*—The use of polarized radiation in infra-red absorption spectroscopy allows the orientation of certain groups in molecular crystals to be determined. This is of considerable importance, for instance, in studies of protein structure, and apparatus has been developed for this purpose.

An absorption cell which enables infra-red absorption spectra to be recorded at temperatures down to that of liquid air has been developed and used in some projects.

The far-infra-red spectrometer using echelette zone plates is now under construction. Many structural problems, especially in the protein field, depend for their solution on a knowledge of the far-infra-red spectrum.

A vacuum ultra-violet grating spectrograph has been designed and is under construction.

(*c*) *Chemical Physics of the Solid State.*—Studies of the solid state were confined to (i) phenomena associated with structural defects, (ii) the properties of the surfaces of solids, and (iii) extremely finely divided solids, which exhibit properties not normally displayed by the bulk solid.

(i) *Defect Solids.*—Structural defects in solids are responsible for the special properties of materials which make possible such articles as fluorescent lamps, many types of radio valve, dry rectifiers, &c.; they are also basic to reactions in solids, of importance in chemical and allied industries, and determine the activity of solid catalysts of gas-phase reactions. The initial studies in this field were concerned with the phenomenon of luminescence. It was shown on theoretical grounds that a study of the behaviour of a luminescent material under periodic excitation is a powerful method of gaining understanding of luminescence, and an apparatus was developed to put this into effect.

An investigation of the properties of luminescent paints for aircraft instrument dials was undertaken for the R.A.A.F., and a tentative specification of a material suitable for service application was drafted.

(ii) *Surfaces of Solids.*—The importance of the state of the solid surface in the flotation of minerals and in bearings was indicated in last year's Report. In the initial studies on metallic surfaces, a theory of the formation and stability of the polish (Beilby) layer was developed and shown to be quantitative by electron diffraction experiments. The structure of a product of the atmospheric oxidation of the Beilby layer was also established.

(iii) *Electron Diffraction Study of Small Crystals.*—Electron diffraction patterns from crystalline particles less than 0.1 micron in diameter display a fine structure, which can arise either from refraction of the electron beam in passing through the crystal or from the limited extent of the crystal. These effects have been studied intensively, since they offer unique possibilities for obtaining important information on the special properties associated with minute crystals and their shapes, and might thus have an important bearing on industrially important phenomena such as catalysis.

(*d*) *Molecular Structure Investigations.*—An essential part of many problems of biology, biochemistry, and chemistry is the elucidation of the molecular structure of certain compounds. Chemical methods commonly permit only an indirect deduction of the structure, and physical methods have been used to allow a more direct analysis. Physical methods are, however, limited in many ways and are not fully developed. The work described here deals with the application of specialized methods to structure analysis and with the development of new or improved methods for this purpose.

(i) *X-ray Crystallography.*—Analyses of the structure of the following compounds are in hand:—Copper colchiceine, in an attempt to establish the structure of the alkaloid, colchicine; the iodo-acetate of dihydrolanosterol, a derivative of an important component of wool wax; certain manganese minerals; the amino acids norleucine, proline, $\alpha$- and $\beta$-methionine, as part of the protein structure programme.

(ii) *Infra-red Spectroscopy.*—A comparative study of the spectra of porphyrins and their derivatives in relation to the biochemistry of the blood pigments was made; the thermodynamic properties of nitrosyl chloride were derived from a new interpretation of the spectroscopic data.

(iii) *Electron Diffraction.*—Secondary scattering in electron diffraction was shown to be important in the application of the technique to structure analysis. The possibility of using measurements of refraction displacements in the pattern fine structure without reference to intensities of reflections is being studied; if successful, this will allow the study of molecular structure of extremely small crystals.

(iv) *Mass Spectroscopy.*—Mass spectroscopy can provide data on molecular bond energies which are not otherwise obtainable. New experimental methods were devised for obtaining these data, and a critical investigation of the methods for analysing results was made. The fully-automatic apparatus devised allows a more reliable estimate of the bond energy to be made than heretofore.

(*e*) *Service Work.*—Many investigations, some amounting to major research projects, have been undertaken at the request of industry, technical institutions and other groups of the Organization. These make use of the specialized techniques established in this Section; the more important investigations are listed hereunder.

(i) *Electron Microscopy.*—Examination of the surface of resin-impregnated wool fibres; estimation of particle-size distribution and characterization of brown-coal ash from test engine exhausts; examination of zinc oxide pigments in relation to paint problems; study of thorium oxide and silver catalysts used for synthetic chemical work; examination of carbon from tar emulsions produced in gas manufacture; investigation of mode of attachment of the particles of Newcastle disease virus on erythrocyte stroma; characterization of various mineral samples, including cassiterites, clays, &c.

(ii) *X-ray Diffraction.*—Identification of the phases n the potassium fluoride-thorium fluoride system; etermination of the crystal structure of a compound ormed during the electrolysis of silver nitrate; eluciation of the superlattice structure in an alloy of ilver and magnesium.

(iii) *Spectroscopy.*—Estimation of undesirable comounds, such as indole and skatole, in milk; use of eflection spectra in following the deterioration of milk roducts under various conditions of storage; detection f traces of barium and strontium in the digestive rgans of various insects, a problem of some signifiance in insect physiology; characterization of strucural features of the compound limonin, the bitter rinciple of oranges, in relation to fruit-juice problems; tudy of the infra-red absorption of organic disulphides nd related compounds; estimation of isomeric content f samples of benzene hexachloride, a commercially mportant insecticide.

(iv) *Mass Spectrometry.*—Analysis of the products f deuteration experiments; various analytical roblems.

(v) *Electron Diffraction*—Examination of a comound formed at the point of failure of aluminium-alloy atigue-test specimens; identification of stains in eiling plaster, a problem concerned with the deterioration of building materials.

(*f*) *Instrument Laboratory.*—A wide variety of equipment has been designed and constructed by the mechanical, electrical, and glass-working shops for this and other sections of the Division.

### 7. Organic Chemistry.

(*a*) *Wool Wax.*—Current investigations aimed at elucidating the composition of this material, which is essentially an ester wax, include: (i) development of physical means for resolving the ester mixture and determining the composition of the fractions; (ii) construction of a modified spinning-band distillation column for low-pressure fractionation of the aliphatic alcohols; (iii) further investigation of the molecular structure of lanosterol; and (iv) further study of the alkaline hydrolysis of wool wax. Details are given in Chapter XV, Section 6.

(*b*) *Sugar Cane Wax.*—This is potentially available in quantity by solvent extraction of the filter muds from the sugar mills. The crude wax is soft and dark, and, before it can find extended use, needs to be hardened by refining and bleaching. Refining is usually accomplished by solvent treatment. It has now been shown that the softer and acidic components of the wax may be removed by heating under reduced pressure, and that the residual hard dark neutral wax closely resembles the product obtained by solvent treatment. This hard wax can be bleached oxidatively with chromic acid to give hard pale yellow acidic waxes. Steps have been taken to patent this refining process.

(*c*) *Alkaloids.*—The investigation of stock poison plants in collaboration with the Division of Animal Health, which commenced last year as a minor problem concerned with the isolation of the alkaloid lasiocarpine from *Heliotropium europaeum,* was extended. Difficulties encountered during the isolation of lasiocarpine led to a more detailed examination of *H. europaeum,* and it is now clear that the plant contains a complex and variable mixture of tertiary bases and their N-oxides. A quantitative method for the determination of those alkaloids is now being sought in order to study seasonal and local variations.

It now seems desirable to examine other native plants likely to contain the hepatoxic pyrrolizidine alkaloids such as occur in *H. europaeum.* Further, an attack is to be made on the group of plants causing locomotory disturbances in animals, and a survey is in progress of the Australian Cycadaceae for toxic pseudo-cyanogenetic glucosides. The majority of Cycadaceae so far tested have given positive results and the macrozamin previously isolated from *Macrozamia reidlei* and *M. spiralis* has been found in *M. miqueiii.*

A number of Australian commercial timbers are reputed to produce adverse physiological effects in man, the effects being most evident when the timber is in a finely divided condition, as in sawdust. Two such timbers are being examined with the object of isolating and identifying the active principles: *Balanops australiana,* which causes nasal irritation and sneezing, and *Dysoxylon muelleri,* which causes severe irritation of the eyes, nose, throat, and lungs. In each, extraction has yielded 1-2 per cent. of a colourless solid. That from *Dysoxylon* is a complex mixture separable by chromatographic methods into a number of fractions, some of which have been obtained in crystalline form. The material extracted from *Balanops australiana* is crystalline and appears to be triterpenoid. The physiological aspects of the *Dysoxylon* investigation have been undertaken by Professor Sir Stanton Hicks of the Physiology Department, University of Adelaide.

Alkaloids from members of the family Rutaceae were further studied. Leaves of *Acronychia baueri* yielded eight alkaloids, four of them acridine derivatives and four furanoquinolines. The former were identified as meliocopine, meliocopicine, melicopodine, and 2, 4-dimethoxy-N-methylacridone, this being the first recorded occurrence of acridine derivatives in the plant kingdom. Three of the furanoquinoline alkaloids were identified as acronycidine, skimmianine, and kokusaginine. The fourth has been named acronidine.

Much structural work in this field was done in collaboration with members of the Chemistry Department of the University of Melbourne. Medicosmine and acronidine (from *Medicosma cunninghamii*) were shown to be respectively the mono- and dimethoxy derivatives of tetracyclic dimethylpyranofuranoquinolines, and the first recorded members of this class. Again, in collaboration with the Chemistry Department, the structures of three alkaloids from *Pentaceras australis* were established as derivatives of a base cantine (itself still unknown), viz., 11-canthinone, 12-methoxy-11-canthinone, and 13-thiomethyl-11-canthinone. Alkaloids from other Rutaceous species under examination include those from *Lunasia amara* and *Micromelum pubescens.*

Work has commenced on the chemistry of the highly toxic and vesicant alkaloid cryptopleurine from *Cryptocarya pleurosperma* (Lauraceae) and the nature of the functional groups has been established. Examination of other *Cryptocarya* species resulted in the isolation from *C. hypospodia* of an alkaloid not identical with cryptopleurine.

(*d*) *Plastics.*—(i) *Kinetics of the Phenol-formaldehyde Condensation.*—The special phenols required for this work were not available commercially and were prepared. Mesitol (2, 4, 6-trimethylphenol) and pentamethylphenol were readily obtained, but the synthesis of prehnitenol (2, 3, 4, 5-tetra-methylphenol) was time-consuming and its purification difficult. Other preliminary work completed included the measurement of the solubilities in dioxane-water mixtures of the reagents, products, and catalysts of the reaction to be studied. Suitable analytical methods for following the reaction under alkaline conditions were also tested.

Experiments showed that in the presence of the inert phenol, mesitol, and under mildly alkaline conditions, the transformation of formaldehyde accorded with a normal Cannizzaro reaction. With the reactive phenol prehnitenol present, the Cannizzaro reaction was by no means suppressed, and was still responsible for 30-90 per cent. of the total loss of formaldehyde. Elucidation of the prehnitenol-formaldehyde reaction is, therefore, not at all simple.

(ii) *Adhesives of Tannin-formaldehyde.*—Batches of this adhesive were prepared from mimosa extract and used by the Division of Forest Products to determine its behaviour in a roller spreading machine. The adhesive gave good dry and wet strengths in the resulting plywood, but as a warm-press adhesive it had a rather short working life.

(*e*) *Heterogeneous Catalysis.*—Information on the mechanism of catalytic dehydration by a thoria catalyst is being sought through measurement of the rates of adsorption of gases by the solid catalysts. This is an extremely rapid process and special apparatus has been developed for the purpose. At the same time, information is being obtained on the structure of the particularly active thoria catalyst obtained by pyrolysis of thorium oxalate.

(*f*) *Other Investigations.*—The reaction between glycerol and hydriodic acid, a method for the quantitative estimation of glycerol, was studied. The mechanism of the reaction, which gives a quantitative yield of the product isopropyl iodide only when an aliphatic organic acid is used as a catalyst, was determined.

Analysis of samples taken of the Kerguelen cabbage (*Pringlea antiscorbutica*), a plant peculiar to the Kerguelen-Heard Island group, has shown that it has a high content of Vitamin C.

At the request of the Division of Animal Health and Production the compound phenylpantothenone, a possible antagonist in bacterial metabolism, was synthesized.

### 8. Chemical Engineering.

Work has continued on a number of projects designed to provide fundamental information of importance for developing methods of chemical engineering design and new methods of processing. Progress has been made in the installation and instrumentation of a wide variety of pilot-scale processing equipment. The units already installed have been used extensively for pilot-plant studies by officers of the Division and by the technical staffs of a number of industrial organizations.

The Section's work, particularly applied research on industrial adsorption processes and fuel utilization, has expanded considerably. The Section has also continued its advisory service to chemical industry, and has provided facilities for the design and construction of equipment for other Sections of the Division.

(*a*) *Distillation.*—The study of equilibrium conditions for the liquid and vapour phases of binary mixtures has been continued and data have been obtained for the systems carbon tetrachloride/cyclohexane at 70° C., benzene/*n*-heptane at 60° C. and 80° C., and ethanol/*n*-butane at 760 mm. Other systems are being studied with the ultimate aim of predicting liquid-vapour equilibria from a knowledge of the structure of the pure components of binary and ternary mixtures.

(*b*) *Solvent Extraction.*—An experimental spray column has been constructed and used to measure the rate of extraction of benzoic acid from aqueous solutions by benzene, for a range of drop sizes and velocities. These results will be combined with previously determined diffusion coefficients for benzoic acid in water and in benzene, in an attempt to determine diffusion film thickness. The object of this work is to develop methods for designing industrial equipment for continuous solvent extraction. It is being done by an officer working at the Chemical Engineering Department, University of Sydney.

(*c*) *Physical Properties of Fluids at High Pressures.*—The laboratory for this work is located in the Chemical Engineering Department, University of Sydney, and was first occupied during 1949. When the necessary high-pressure equipment is installed, fundamental studies will be made of the physical and thermodynamic properties of compressed fluids. During the course of this work the Section will collaborate with similar English and American laboratories in preparing tables and charts of physical and thermodynamic properties of industrially important fluids and fluid mixtures.

Pending the installation of the high-pressure equipment, experimental work has been undertaken on two topics which, while relevant to the investigation, do not require extensive high-pressure equipment. These are—

(i) Determination of second virial coefficients for gases and vapours by a procedure designed to permit greater accuracy of measurement than that obtainable by existing methods. The second virial coefficient of a gas or vapour, which represents the initial departure of the gas from the ideal behaviour, is important at relatively low pressures.

(ii) A study of the effect of solvation on the dipole moments of molecules in solution in hydrocarbons under pressure.

(*d*) *Development of Adsorption Processes.*—At present there is no satisfactory industrial process analogous to fractional distillation for the separation of complex mixtures such as sea-water, fermentation process wastes, sewage, high boiling point mixtures of hydrocarbons, fats, oils, and waxes. However, the components of mixtures of this kind can be selectively removed by adsorption on finely divided carbon or other adsorbents from which they can subsequently be removed (desorbed). This method of fractionation should be commercially attractive if it can be developed into a continuous process in which desorption can be effected without the use of organic solvents.

The Section has made considerable progress in the development of two adsorption processes, namely a vat process having a large throughput, and a column process having a smaller throughput but giving more effective fractionation. Success was also achieved in modifying the surface of adsorbents to render them more selective, and in using froth flotation to obtain counter-current flow. These advances have made it possible to operate these processes effectively on a continuous basis.

The vat process has been operated continuously for some time, and it has been demonstrated that large quantities of liquid can be processed with negligible losses of adsorbent and flotation agent. In developing the continuous column process, simple equipment has been evolved which has the advantages of effective fractionation and ease of operation.

Work has continued on the development of improved absorbents, particularly modified carbon adsorbents, and a study has been made of the co-adsorption on activated carbon of insoluble non-electrolytes, particularly flotation reagents, and of soluble weak organic electrolytes.

The Section is also developing an industrial process for using ion exchange resins, which differs from the conventional procedure in that adsorption occurs as a result of the selective short-range adsorptive forces, and the electrostatic forces are utilized only during the desorption stage.

(*e*) *The Study of Fine Particles.*—To study the behaviour of fine particles suspended in gas or liquid media, methods were developed for preparing uniform spherical particles and measuring their size. During the year a comparison of the flow of fluids through suspensions and beds of these particles was commenced; this was made possible by the development of xtremely thin filter membranes with negligible esistance to fluid flow. The aim of the work is to btain basic information which can ultimately be pplied to such processes as filtration, sedimentation, ickening, and dust and fume removal.

(*f*) *Fuel Utilization.*—This work is described in hapter XIX., Sections 3 and 4.

(*g*) *Unit Operation.*—Pilot-scale chemical plant quipment installed in this laboratory has been used uring the year by officers of the Division for the xtraction of alkaloids from Australian plants, for he extraction of wool wax alcohols, and for the urification by fractional distillation of various rganic intermediates. This equipment has also been nade available to private companies for work on the pray drying of various materials, for vacuum and ressure filtration, and for the digestion and pulping f cellulosic materials.

## XVIII. MINERAGRAPHY AND ORE-DRESSING.

### 1. General.

The importance of investigations for the development of the mining industry and the utilization of Australia's mineral resources is recognized by the Organization.

Mineragraphic work to provide information on the mineral composition of ores has been in progress in Melbourne since 1927. Investigations of ore samples have been made to provide advice on the most suitable methods of treatment and are described in Section 3 of this Chapter.

Work within the Division of Industrial Chemistry on the utilization of minerals is described in Chapter XVII, Section 2. Other work within that Division on the flotation of minerals is dealt with in Section 4 of this Chapter.

### 2. Mineragraphy.

Thirty-one investigations have been carried out into the mineral association of rocks, drill cores, and mill and smelter products submitted by mining organizations and institutions. Each investigation was directed to some specific problem relating to the occurrence or recovery of the valuable mineral. Thirteen of these investigations related specifically to the intensive search for new mineral deposits which is being carried out by some of the larger mining corporations. Five were concerned with ores which were subjected to experimental treatment in the Ore-dressing Laboratories, or with the products of such treatment.

Following study of the mineral composition of the large lowgrade ore body at Big Bell, Western Australia, an investigation was undertaken into the nature of the gold losses in the mine tailings. Such investigations are imperative for the continued existence of marginal gold mines in face of rising costs. The Big Bell mine is in this category and a prolonged examination was made of the tailings containing about 0.5 dwt. per ton. This loss represents about 16 per cent. of the total gold in the ore, and it is obvious that the smallest improvement in the treatment of the large tonnages put through the mill is of vital importance. The investigation showed that, while some of the gold was lost because it was locked up in mineral particles and therefore not exposed to solution in cyanide, other gold particles were free. The proportion of locked to exposed gold could not be determined but the results suggested that the proportion of unrecovered exposed gold was important. Ore-dressing investigations are thus directed towards variations in treatment by which the loss of such exposed particles can be reduced.

Mineragraphic methods have been applied to the study of the composition of copper slags and copper mattes at Port Kembla. Copper in the blast furnace slag is due chiefly to droplets of cuprous sulphide trapped in the meshwork of olivine crystals. This cuprous sulphide contains a little dissolved metallic copper which separates out on cooling. The metallic copper is replaced by cuprous oxide (cuprite) in slowly-cooled slags. Arsenic and antimony separate as copper compounds enclosed in chalcocite. In the converter slag the copper resides in droplets of cuprous sulphide and metallic copper.

Mattes containing more than 60 per cent. copper crystallize essentially as a solid solution of chalcocite and cuprous sulphide in bornite which separates on cooling into oriented intergrowths of the two components. Chalcocite predominates in the more copper-rich mattes and bornite predominates in those approaching 60 per cent. copper. Mattes with 30-60 per cent. copper crystallize as two solid solutions with a eutectic relationship to each other. One is bornite-rich and the other has a composition between cubanite and chalcopyrite, approximating to $Cu_3Fe_4S_6$. Mattes with about 30 per cent. copper approach the eutectic composition, while mattes richer in copper have the bornite solid solution in excess of the eutectic. Metallic copper, held in solution in molten cuprous sulphides, is deposited on cooling in contraction cracks. Lead sulphide in the Kembla matte is found partly as eutectic intergrowths with bornite and partly as coarse grains included in the copper-arsenic-antimony compound.

An examination was made of a drill core through a section of the zinc lode at the New Broken Hill Consolidated. Quartz, often bluish from the presence of needles of rutile, is the chief gangue mineral, while garnet is moderately abundant. Among the rarer gangue minerals, one specimen revealed a few grains of bastnasite, a rare fluo-carbonate of the cerium metals. Ferriferous zincblende is the chief ore mineral in the core and is associated with varying small quantities of galena. Other sulphides, including chalcopyrite and tetrahedrite, generally form less than 0.5 per cent. of the sections. They include some of the rarer sulphides of the Broken Hill lode such as dyscrasite in galena, jamesonite as needles lying across the galena-blende contacts, bournonite along galena-tetrahedrite contacts, inclusions of cubanite and valleriite in chalcopyrite, and inclusions of gudmundite in blende, tetrahedrite, and gangue. Analyses of the cores indicated traces of bismuth but the search for its location was unsuccessful.

The investigations have been facilitated by contributions from a number of mining companies through the Australasian Institute of Mining and Metallurgy. The University of Melbourne has also co-operated in providing laboratory accommodation in the new extensions of the Geology Department.

### 3. Ore-dressing Investigations.

Ore-dressing investigations are being carried out in co-operation with the Kalgoorlie School of Mines. Much attention was given to the testing of various mine dumps for the possibilities of extracting the gold from them by cyanidation. A number of requests were also received involving tests aimed at the determination of the best method of treating ores; such requests came from Marble Bar, Calyerup Creek, Cordoroy, Gabanintha, and several other localities where gold is found. The facilities of the laboratory were also in considerable demand for infrasizing tests of mill products such as slimes as a guide to improving the metallurgical treatment adopted by the large mines of Kalgoorlie and elsewhere.

At Melbourne, where work is carried out in co-operation with the Department of Mining of the University, twenty reports were issued. Of these, six relate to beach sands, five to gold ores and tailing dumps, and the remainder to ores of tin, lead, copper, and bismuth, and to iron oxides, brown coal, and talc. Twenty-nine investigations, mainly relating to the treatment of gold and tin ores and dumps and to the recovery of tin and monazite from beach sands, were in hand but incomplete at the end of the period under review.

The electrostatic separator designed and constructed in the laboratory has been modified by installing sheet electrodes, one on each side of the stream of falling particles. With these charged at opposite polarities, greater separating efficiency was attained and satisfactory separation of zircon from rutile was achieved. These are two of the valuable minerals which may be recovered from beach sands which occur along the eastern Australian coast and elsewhere. Combinations of magnetic and electrostatic methods of separation have also been used to recover monazite and cassiterite from beach sand concentrates.

Difficulties associated with the acid leaching and recovery of bismuth from an ore occurring in an isolated and arid region have been investigated. A lead ore from western New South Wales and a copper ore from Queensland each contained appreciable quantities of oxides and carbonates of the valuable metals. Further work is in progress designed to establish conditions for good recovery of such minerals by flotation concentration.

### 4. Flotation Investigations.

In flotation the surface of a mineral under water is modified (conditioned) so that a bubble of air may make contact with it and buoy it up into a froth. By measuring the amount of a soap (sodium cetyl sulphate) adsorbed on a known area of cassiterite surface under various conditions, the mechanism of the conditioning process in this system is being studied. The actual contact between bubble and mineral in a flotation cell occurs so rapidly that the process cannot be recorded by high-speed photography. An apparatus has been devised which, in effect, retards contact so that some of the factors which govern the process may be studied in detail. From a knowledge of these factors it is intended to determine whether the process of contact can be accelerated in the flotation cell, thereby increasing the capacity of a flotation plant.

Where long paraffin-chain compounds are used as collectors it is difficult to produce the brittle unstable froths necessary for selective flotation. This is true, for instance, of the flotation of the important ore minerals, scheelite (tungsten) and cassiterite (tin). It has been found that the difficulty arises from an interaction of the collector with the commonly used frothers. The nature of this interaction is being studied by measuring the surface tensions and surface viscosities of the solutions in relation to their frothing characteristics. A parallel approach to the problem of frothing is being made by measuring the persistence of single bubbles as a unit of froth.

## XIX. FUEL.

### 1. General.

The Coal Research Section, at Ryde, New South Wales, has engaged in work preparatory to its projected survey of the chemical and physical properties of Australian coals; certain investigations have already begun (*see* Section 2 below). The Mineragraphic Section, located at the University of Melbourne, and the Botany School of that University, have completed a number of researches on the chemistry and micro-structure of brown coals from Victorian and South Australian deposits (*see* Section 3 below). Preliminary problems relating to the complete gasification of brown coal from the Latrobe Valley, Victoria, have been studied by the Chemical Engineering Section of the Division of Industrial Chemistry (*see* Section 4 below).

### 2. Coal Research Section.

The erection of three semi-permanent single-storey buildings at North Ryde, New South Wales, was begun in October, 1949, and they should be completed early in the coming year. Meanwhile, the preparatory work for the Section's activities proceeds under difficulties in a small temporary laboratory, first occupied in April, 1950. During the year the temporary offices were extended to provide more space for the library relating specifically to fuel research which is being established.

In its survey of the chemical and physical properties of Australian coals, the Section will work in close collaboration with the various Coal Boards, State Departments of Mines, Geological Surveys, and other authorities.

An investigation into the gas-making, coke-making, and by-product-making properties of Australian coals is being undertaken in cooperation with the National Gas Association, using equipment located in the Association's laboratories in Melbourne. To establish a basis for comparison, samples of the Greta Seam have been tested, and the Lithgow Seam is now being investigated.

Petrological investigations carried out during the year included a study of the spore content of coals from borehole samples in the Styx River area, Queensland, and an examination of thin sections prepared from a pillar sample of the Greta Seam, New South Wales.

At the Geology Department of the University of Sydney, fundamental petrological studies are to be made on a co-operative basis. These will include *inter alia,* a study of coke structure using X-ray techniques, an investigation of the occurrence and distribution of mineral matter in coal, and an investigation of the chemical variation and characteristics exhibited by vitrains and fusains throughout Australian coal-fields.

### 3. Chemistry and Microstructure of Brown Coals.

A collaborative study of fossil Banksiae in the Yallourn seam was carried out by the Botany School of the University of Melbourne. The leaves and cones of seven fossil species and 100 living species of *Banksia* and the closely related genus *Dryandra* were described.

Preliminary studies of the pollen in lignites from the Lake MacDonnell and Pidinga No. 15 bores in South Australia were made. Many of the pollen grains in these bore cores are types that have not yet been studied in sufficient detail to be identified. These were drawn or photographed and recorded for future study. Counts of the pollen at intervals in the bore cores showed fluctuating proportions of the various types, with an overall dominance of *Nothofagus* varieties, suggesting that the beds belong to the Middle Tertiary period. Short reports of a similar nature on brown coals from Flinders and Benwarrin, Victoria, were also prepared.

The Mineragraphic Section completed two short studies dealing respectively with effects of folding on the moisture content of brown coals, and with coal types in the Maddingley, Victoria, brown coal seam. A third paper described a new method of classifying coals in terms of the fixed carbon content of vitrain and run-of-mine coal, on a pit-moist, ash-free basis.

The Division of Industrial Chemistry made pre-minary studies of specimens of resin from the Yallourn am, to determine its likely economic value. The resin as found to have physical and chemical resemblances Congo copal resin. Preliminary investigation by the re-Dressing Laboratory, Melbourne, showed that it uld be separated electrostatically from air-dried brown al. The Division is now pursuing this study, to scover the resin content of the Yallourn coal.

The preparation and examination of brown coals . thin sections has continued at the Botany School. riority was given to the examination of bore cores of :oorlands brown coal, South Australia, but Morwell ad other Victorian coals will be examined during 950.

### 4. Gasification of Brown Coal.

The Chemical Engineering Section's programme of uel utilization research has been considerably expanded uring the year. At present, work is centred around ne investigation of the problems involved in the comustion and in the complete gasification of brown coal rom the Latrobe Valley, Victoria. The complete gasication of brown coal is being investigated with wo aims: (i) production of a gas suitable for the ynthesis of liquid fuels and chemicals; (ii) production f a gas of high calorific value suitable for distribution s a town gas. Possible methods of gasification were onsidered in relation to the properties of this coal and o developments overseas, and it was decided initially to nvestigate fluid-bed gasification procedures at elevated ressures for both purposes. The two small-scale plants now in the course of development will be of the ninimum size to supply adequate data on the chemistry of the processes and the characteristics of the fuel beds, and to serve as a testing ground for the devices developed from study of the many associated problems, such as dust removal and gas cleaning, ash removal, and coal feeding.

Investigation of fluid-bed gasification and fluid-bed carbonization of brown coal, and studies of the kinetics of the gasification reaction of brown coal chars, are also in progress.

## XX. PHYSICAL METALLURGY.

### 1. General.

The Section of Physical Metallurgy continues to work in conjunction with the Research School of Metallurgy in the Baillieu Laboratory at the University of Melbourne, under the general direction of the Research Professor of Metallurgy.

The work on the strength and structure of metals, a collaborative project with the Aeronautics Laboratory of the Ministry of Supply (formerly the C.S.I.R.O. Division of Aeronautics) has continued, attention being paid to the mechanism of failure of metals by fatigue and to the influence of rate of strain on the mechanism of deformation at high temperatures.

The main work of the Section, however, has consisted of a study of the constitution and properties of the alloys of titanium, of the allotropy of titanium, and of the influence of prolonged stress on the deformation of alloys of lead.

The equipment of the Section has been made available to the staff of other laboratories, in particular to the Division of Tribophysics, the Aeronautics Laboratory, and the Metallurgy School of the University.

### 2. Titanium and its Alloys.

Some pure titanium prepared by the thermal reduction of the iodide was procured during the year to supplement the supply of "Kroll" titanium donated by the United States of America Bureau of Mines.

The allotropic transformation at 882° C. was examined by the hydrogen-pressure method developed in the Section, by electrical resistance, and by thermo-electric force determinations. The transformation was shown to be isothermal—a point on which some doubt had been thrown by earlier work—and the changes in properties are of sufficient magnitude to be used for examining phase relationships. In Kroll titanium, owing to the presence of impurities, the transformation is spread over a range of about 100° C.

The constitution of several alloy systems has been determined. Using pure titanium, the system hydrogen-titanium was examined up to concentrations of the order of 60 atomic per cent. hydrogen, as this system is utilized in the hydrogen-pressure method for examining other systems. Some thermodynamic relationships relating to the system were also examined.

The influence of iron, copper, and chromium on the $\alpha$ $\beta$ allotropic change has been studied as far as 5 atomic per cent. of each element. In each case there is a lowering of the allotropic change temperature. The hydrogen-pressure method was used. The solid solubility of these elements in the $\alpha$ form of titanium has been shown to be very low in spite of a favorable atomic size factor. The solubilities are: copper, less than 1 atomic per cent., and iron and chromium, less than 0.1 atomic per cent.

Using Kroll titanium (containing about 0.3 per cent. impurities), a constitution diagram for alloys containing up to 50 atomic per cent. iron has been worked out by microscopic and X-ray diffraction methods. The system is eutectiferous, the melting point of titanium being rapidly lowered by additions of iron. In the solid state, the system shows a eutectoid change at about 600° C. The mechanical properties of alloys subjected to various heat treatments based on the diagram have received preliminary examination. It has been shown that a 4 per cent. iron alloy, after quenching followed by aging treatment, can develop a tensile strength of the order of 100 tons/sq. in. with 4-5 per cent. elongation.

Also using Kroll titanium, preliminary work on the constitution of oxygen-titanium alloys has been carried out. It has been shown that oxygen raises the allotropic transformation temperature. Dissolving of oxygen considerably raises the hardness of titanium.

This latter fact has been used to create a hard surface layer by exposing titanium to oxygen at various temperatures and pressures. It has been shown that it is possible to increase the surface hardness up to 600 D.P.N. by increasing the oxygen concentration.

### 3. Creep of Lead Alloys.

The creep characteristics of a very pure industrial lead have been examined under stresses of 150-500 lb./sq. in. The specimens were extruded in the laboratory, and in checking the absence of strain in the specimens after annealing it was found that a skin effect was present. This did not systematically affect the creep rate but gave a misleading idea of the annealed state. Removing 0.001 inch by etching was satisfactory.

Addition of tin to lead (0.01 to 0.9 per cent.) within the limits of solid solubility was made. Extruded and annealed specimens were stressed at 500 and 300 lb./sq. in. respectively. At the higher stress, the creep rate decreased with increasing tin content, but at the lower stress, tin concentration made no significant difference.

Additions of thallium to lead have also been made. This element has a much higher solid solubility range than tin. Alloys carrying between 0.5 and 40 per cent. thallium have been prepared, and test specimens made by extrusion and annealing. Both at 500 and 300 lb./sq. in. stress the creep rate is a complex function of composition and further work is in progress.

An alloy containing 2.5 per cent. thallium is being used to check the effect of strain rate on the mechanism of creep. Microscopic and X-ray back-reflection techniques have given results conforming with those obtained by other workers in the laboratory on aluminium.

## XXI. TRIBOPHYSICS.

### 1. GENERAL.

*Division of Tribophysics.*—During the year further progress has been made in the development of the three main fields of activity with which the Division is concerned: (*a*) friction and lubrication, (*b*) metal physics, and (*c*) reaction kinetics. The work has been hampered, however, by lack of space, and it is disappointing to record that the building of the new laboratory has not yet begun. The Division still has to rely on Professor Hartung's hospitality for its main laboratories in the Chemistry Department of the University of Melbourne, and is deeply indebted to him and to the University for his continued generosity.

Assistance and advice have been given to industrial firms, Government organizations, and University departments on a wide variety of problems relating to lubrication and bearings, metallurgy, electronics, and electrolytic polishing. Members of the Division are acting on various committees, in particular the Engineering Group Committee. The metallurgical colloquia held with other metallurgical groups continue to be an important medium for the exchange of specialized knowledge.

Co-operation with the Chemical Physics Section of the Division of Industrial Chemistry has yielded valuable information on the structure of lubricating films on metals and is being continued with mutual benefit.

A Goldsmith Dominion Travelling Scholar from the University of Cambridge is working with the metal physics group.

The active co-operation of the Physics, Metallurgy, and Engineering Departments of the University of Melbourne has continued during the year.

### 2. FRICTION AND LUBRICATION.

The solution of problems of friction involves the accurate measurement of frictional forces, the determination of the extent of surface damage of the sliding surfaces, and a knowledge of the basic function of lubricants. Practical and fundamental aspects of these factors are being investigated.

(*a*) *Friction.*—One of the main causes of the resistance between materials in sliding contact is the continual formation and shearing of minute points of adhesion as welding occurs between the asperities of the surfaces. More detailed knowledge of this process would conduce to more efficient lubrication, reduced wear, and simplified maintenance problems.

(i) *Surface Deformation due to Friction.*—The shearing of metallic junctions causes deformation extending below the surface, which may be so far-reaching that oxide particles, originating at the surface, are found at considerable depths. Further evidence for the intense working in this zone has been obtained by comparing the frictional work with the work necessary to deform this zone.

(ii) *Friction and Hardness.*—It appears that hard metals are generally associated with low friction. Definite evidence of this has been obtained with copper-beryllium alloys. Specimens of these alloys can be heat-treated to give a wide variation in hardness along their length, and experiments on these specimens show that friction is reduced as the hardness increases.

(iii) *Friction and Surface Finish.*—Frictional forces can also arise from the "ploughing" of the irregularities of the sliding surfaces. This effect can be calculated if the profile of the surface is regular. In collaboration with the Defence Research Laboratories gold surfaces with regular contour have been prepared by ruling with a specially shaped diamond tool, and replicas of these are being made in nickel. Preliminary experiments on the friction of these prepared surfaces are giving results which conform to the theory.

(*b*) *Lubrication.*—Under conditions of high loads and slow speeds, a state of "boundary lubrication" may occur, where the surfaces sliding over one another are separated only by an extremely thin film of lubricant in place of the normal substantial film. If seizure is to be prevented under these conditions, efficient boundary lubrication is essential; and as such boundary lubrication occurs very frequently in practice, an understanding of its basic mechanism is of first importance.

Efficient boundary lubricants of one type contain very small concentrations of polar long-chain compounds, which are adsorbed firmly on the surfaces as monomolecular films. In acids subsequent reaction with the metal surface may occur and a film of a metallic soap may be formed.

(i) *Lubrication by Thin Films.*—The effectiveness of thin-film lubricants must depend on their behaviour under shearing forces. This was investigated by depositing thin films of long-chain normal acids and paraffins on polished metal surfaces and subjecting them to sliding shear. Variations in the applied pressure had no appreciable effect on the subsequent film structure as examined by electron diffraction methods.

In general, "rubbed" films consist of a tightly-bound monomolecular film with excess material lying on top of it in the form of small crystals, oriented with respect to the direction of rubbing. It was observed that such crystals had been "deformed" by sliding shear, i.e., the crystal symmetry and cell dimensions had altered. The possibility of producing oriented crystals on top of an adsorbed monolayer seems to depend on the chain length and chemical composition of the long-chain compound, and the nature of the underlying metal surface. Further work along these lines is in progress.

(ii) *Spreading of Liquids on Solids.*—While it is generally desirable that a lubricating oil should spread readily over moving surfaces, there are cases, as in the lubrication of instrument mechanisms, where unlimited spreading has to be avoided. The presence of adsorbed films on the metal surface has a marked effect on the spreading, which in some cases may be prevented altogether. Study of the manner and rate of spreading of various oils over clean polished metals and the influence of small concentrations of long-chain polar compounds is being continued.

(iii) *Adsorption.*—The adsorption of long-chain polar compounds on metal surfaces from solution is being investigated. The metals are used in the form of very fine powders, enabling the slight decrease in concentration of the solution to be measured by a new sensitive technique. Adsorption appears to be reversible in most cases, indicating that surface reactions do not occur at the low temperature used.

(iv) *Piston-ring Lubrication.*—Continuous measurement and recording of the electrical resistance of the oil film between piston rings and cylinder of a small petrol engine was used to investigate the stability and form of the film under various operating conditions. Particular attention was given to the state of lubrication during run-in of new surfaces, as in the sleeve-bearing work described in (v). The possible correlation between engine wear and oil-film breakdown is being examined.

(v) *Bearing Testing.*—Running tests with white metal sleeve bearings showed that the ability of a bearing to "run-in" is influenced by geometric errors of shaft and bearing, rather than by normal variations in loading or in length-diameter ratio. Satisfactory machining techniques have been developed which avoid these geometric errors, and experiments are being continued to study the effects of clearance and very small length-diameter ratios. Some preliminary results were given in a paper presented to the Mechanical Branch, Melbourne Division of the Institution of Engineers, Australia, in September, 1949.

### 3. METAL PHYSICS.

The work centres about the two main problems, plastic deformation and phase changes. Plastic deformation occurs in such processes as rolling, wire drawing, extrusion, and forging. Phase changes are accompanied by changes in properties of metals and alloys, and are the basis of the common methods of producing metals with specified properties (heat treatment of steel, age-hardening of light alloys, &c.). Any increase in our knowledge of these processes will immediately widen the range of materials available to industry.

(*a*) *Plastic Deformation.*—(i) *Measurement of Energy Stored in a Metal During Deformation.*—The quantity to be measured is very small and an apparatus of extremely high accuracy is needed. The original calorimeter did not meet all the requirements and a completely new apparatus has been built. Preliminary measurements indicate that this apparatus will be satisfactory.

(ii) *Deformation of Two-Phase Alloys.*—The influence of the volume proportion of the harder phase on the deformation of two-phase alloys is of importance to industry, since the majority of alloys used contain at least two phases. Work has continued with copper iron alloys, and has shown that here also the harder phase is deformed more heavily when present in a greater proportion.

(iii) *Change in Electrical Resistivity due to Cold Working.*—The increase in electrical resistivity on rolling has been found to vary with the direction of measurement in the sheet. This induced anisotropy is of the order of a few per cent. of the total increase, and has been explained qualitatively by a theory which connects the mechanism of plastic deformation with the change in electrical resistivity.

(iv) *Recrystallization of Zinc.*—A new method has been developed which permits the growth of new crystals to be followed photographically during recrystallization. Several series of photographs have been taken and some new features of grain boundary movement have been observed, e.g., the growth has been found to be erratic, probably because of the variation of internal stresses from grain to grain and even within the one grain.

(*b*) *Phase Changes.*—(i) *Diffusion.*—The use of radio-active isotopes has enabled the rate of self-diffusion in polycrystalline tin to be investigated qualitatively by the darkening of photographic film. Results were found to be in agreement with previous measurements of the rate of self-diffusion in crystals of different orientations. The rate of diffusion along the crystal boundaries is generally considerably higher than that of volume diffusion, implying an increase in diffusion rate as the crystal size decreases.

(ii) *Order-disorder Transformations.*—The existence of a new superstructure in $\alpha$-phase silver-magnesium alloys has been proved by X-ray and electrical resistivity measurements. The structure of the superlattice is very complex.

### 4. REACTION KINETICS.

The work of the kinetics group has been confined so far to the study of reactions in solution and in the gas phase, but an extension to reactions involving the solid state is envisaged.

Oxidation of organic substances by the atmosphere is of widespread occurrence; thus it is responsible for the "gumming" of lubricants and is one important cause of "knock" in internal combustion engines.

Problems in the physical chemistry of oxidation reactions are being attacked by studying the kinetics under conditions eliminating many of the inherent complexities of the reactions. The reactions investigated are oxidation of aldehydes in solution and oxidation of simple hydrocarbons in the gas phase.

### 5. MISCELLANEOUS.

(*a*) *Electronics.*—The development of apparatus for measuring X-ray intensities with Geiger counters has continued. The two Geiger counter spectrometer units including decade counters, power supplies, spectrometers, and curved crystal monochromators have been completed and found to function satisfactorily. Preliminary measurements of line intensities showed that rolled sheet specimens were unsuitable because of the presence of a pronounced preferred orientation. Better results are now being obtained with specimens of metal powders.

A suitable method was developed for measuring a small difference in power input to two similar furnaces in the apparatus used for the measurement of stored energy (Section 3 (*a*) (i)). The final apparatus, a differential dynamometer wattmeter, has just been completed. The electronic temperature controllers associated with the apparatus were tested and found satisfactory.

In addition to these major projects, various pieces of electrical and electronic apparatus were designed and constructed for other groups in the Division.

(*b*) *Electrolytic Polishing.*—The manual on electrolytic polishing issued last year is still in demand and the Division receives many inquiries on methods of electrolytic polishing from industrial users and research laboratories in Australia and overseas.

The facts relating to this technically important subject are still largely empirical and investigations are in progress to determine their fundamental basis.

## XXII.—NATIONAL STANDARDS LABORATORY.

### 1. GENERAL.

The National Standards Laboratory was founded in 1938 as a result of the Commonwealth Government's decision to extend the activities of the Council for Scientific and Industrial Research to secondary industry. The Secondary Industries Testing and Research Committee, set up by the Government to prepare a plan for this extension, recommended *inter alia* that a National Standards Laboratory be established to maintain the physical standards of measurement for the Commonwealth, and to provide means for the calibration of secondary and working standards. These subsidiary standards are a fundamental requirement for the effective development of secondary industry, particularly in those branches in which high precision and interchangeability of parts are essential. The Committee's report also pointed out that the establishment of a National Standards Laboratory would enable the Weights and Measures administration of the various States to be based on Commonwealth standards, as was the wish of the 1936 Conference of Commonwealth and State Ministers.

The Laboratory is situated in the grounds of the University of Sydney. During the war years the staff was engaged almost entirely on war problems, and the establishment of the primary standards was consequently delayed, but the Laboratory is now able to meet most demands for the calibration of precision equipment in terms of internationally recognized standards of measurement.

The *Weights and Measures (National Standards) Act* 1948, passed by the Parliament in accordance with Section 51A of the Constitution, makes the Organization the custodian of the national standards. Under this Act, the States will continue the administration of weights and measures matters affecting trade and commerce, and the States' standards of measurement will be derived from the Commonwealth standards maintained by the National Standards Laboratory.

The same Act provides for a National Standards Commission to advise the Commonwealth Government on weights and measures. This Commission was recently set up and consists of Professor L. G. H. Huxley, Professor of Physics at the University of Adelaide, as Chairman, the Chiefs of the three Divisions of the National Standards Laboratory, and Mr. W. M. Holmes, formerly Superintendent of Weights and Measures for Victoria.

One of the first tasks of this Commission will be to make recommendations for Regulations under the Act, to define the Commonwealth legal units and standards of measurement, and to prescribe the requirements for co-ordinating the reference standards of the States with the Commonwealth standards.

Maintenance of standards of measurement and calibration of measuring equipment is undertaken by the National Standards Laboratory to meet the requirements of—

(1) The Weights and Measures administrations of the various States.
(2) Government and semi-Government authorities, for purposes outside the Weights and Measures Acts.
(3) Industry and scientific research, for precision measurements generally.

The second and third require the maintenance of standards of measurement not concerning the Weights and Measures administration. The third, particularly, sets the Laboratory its most difficult technical problems in maintaining standards of the required accuracy.

The statutory functions of the National Standards Laboratory in maintaining standards, testing, and calibration are carried out by the Divisions of Metrology, Physics, and Electrotechnology, in the following special fields:—

*Metrology.*—Length, mass, time, and the physical quantities directly derived from these, such as area, volume, force, and pressure. The needs of industry in these fields inevitably involve this Division in certain aspects of applied mechanics.

*Physics.*—Heat, which involves maintaining the International Temperature Scale; light, including candle-power, luminous flux, illumination, colour measurement; viscosity; the primary electrical standards of resistance and voltage.

*Electrotechnology.*—Resistance and voltage other than the primary standards, capacitance, inductance, power, frequency, magnetic quantities, the maintenance of standards of measurement of these quantities both for direct and alternating current over the range used in industry and in research.

As industry and technology develop it may become necessary to extend the range of physical standards maintained by the Laboratory. So far it has not been considered necessary to set up standards in acoustics although some acoustical work has been carried out by the Division of Physics.

The three Divisions of the Laboratory also carry out researches on matters directly related to the maintenance of standards and precision measurement, and on problems of a more fundamental nature.

The Laboratory has facilities for calibrating and testing measuring equipment, and provides an important service to industry by giving advice on methods of measurement and by investigating special problems.

Fuller details of the work of the constituent Divisions are given in the following three chapters.

## XXIII. METROLOGY.

### 1. General.

To maintain the accuracy of measurement essential for efficient production in many industries, equipment must be calibrated periodically against working standards of measurement, which must in turn be checked against national standards. The Organization's Division of Metrology is responsible for the Commonwealth Standards of measurement of length and mass and associated physical quantities, and undertakes research concerned with precision measurements in these fields and with applied mechanics.

The work of the Division of Metrology in the past year has been largely directed towards meeting the anticipated requirements of the National Standards Commission and so enabling the Weights and Measures (National Standards) Act 1948 to be proclaimed. As mentioned in the previous Annual Report, the standard scales of one yard and one metre have been received, and will form the basis of the Commonwealth legal standards of length.

Towards the end of September the universal comparator arrived from overseas and it has now been installed. This will permit all measurements to be determined in terms of the Commonwealth standards. The geoditic base has arrived from overseas and when installed will enable longer lengths, such as surveying tapes, to be calibrated with reference to the standard yard or metre.

The Standards Association of Australia, the National Association of Testing Authorities, various advisory councils of the Department of Technical Education, and similar bodies have taken advantage of the assistance that can be given by the Division. A number of inquiries have also been received from industrial sources. Interest in the Division's work has been reflected in requests by public bodies and scientific institutions for addresses and lectures in a number of industrial centres.

Publications now in preparation will describe the activities of this and other Divisions of the National Standards Laboratory, and the facilities available for undertaking various classes of tests for industry (*see* also Chapter XXII).

### 2. Measurement of Length and Associated Quantities.

(*a*) *Universal Comparator.*—The foundations of the universal comparator were satisfactorily completed by the Department of Works and Housing towards the end of 1949. The comparator has now been assembled and aligned by the Laboratory Staff and the electrical installation completed.

This comparator was made by the Société Génévoise and embodies all the experience of that well-known firm, which specializes in the manufacture of standards equipment. It incorporates many improvements on earlier models, particularly in the microscopes, which now have rotatable bodies. This feature was first introduced by the International Bureau of Weights and Measures.

Test comparisons of scales indicate that the whole assembly is functioning correctly.

(*b*) *Geodetic Base.*—The foundations for the geodetic base have been laid and a start made with the alignment of the 47 concrete pillars. One set of surfaces of these pillars must be aligned to within ±0.04 in. of a common vertical plane extending over the 50-metre length of the base, and another set of surfaces to within ±0.02 in. of a common horizontal plane.

The complete measuring equipment for the base has been received from overseas and will be assembled on the pillars when these are ready.

It is proposed to make use of the well-known sag-wire method to obtain information on changes in length of the base. Four sag-wires will be fixed at the ends to the most important pillars of the base, and changes in the distance apart of each pair of pillars will be determined by measuring changes in sag of the wire. Invar wire for this purpose has been received from overseas, and its coefficient of expansion and other properties measured. Preparations have been made for the installation of the wires as soon as the pillars have been set up.

Electronic temperature control equipment already applied to control the air temperature of a large room has proved so satisfactory that it is proposed to apply similar equipment to the tape corridor.

An electronic controller has been built for the tape corridor which will operate a 2-kVA transductor. The latter is separately mounted in a unit incorporating thermostatic protection against excessive temperature rise in the air duct. A preliminary trial of the performance of this equipment will soon be made.

(*c*) *End Standards.*—The normal programme for the maintenance of end standards has been continued.

The level comparators used for the calibration of end bars are, as is usual, enclosed in glass cases to improve temperature conditions. Some time ago remote controls were fitted to one of the comparators so that a complete comparison could be performed without opening the case. This arrangement proved very satisfactory and remote controls, modified as a result of the experience gained, have now been fitted to both level comparators.

To effect a further improvement in temperature conditions, an electronic temperature controller will be applied to these instruments.

(*d*) *Interferometry.*—Development of new methods for the standardization of length and angle by interferometry is progressing, and multiple-beam interferometry is being applied to a variety of problems of fundamental interest.

Work on wavelength standards has been delayed by the difficulty in obtaining suitable material from overseas for the construction of instruments required in this work.

Equipment for producing highly reflecting films on glass surfaces by evaporation and sputtering processes has been received, and will contribute greatly to the progress of work in hand. A photographic laboratory also has been organized as an integral part of the Interferometry Section.

(i) *Calibration of Angle Gauges.*—The Division's angle standards are being measured successfully by interferometry with a precision of the order of 0.1 second. The method has revealed distortion occurring in the surfaces during use.

(ii) *Surface Finish Standards.* — The absolute calibration of glass surface finish standards by multiple-beam interferometry has been completed. The precision is such that minute irregularities of the order of 10 angstroms ($10^{-3}$ micron or 4 x $10^{-8}$ in.) in depth were measurable. The production of these surface finish standards and their calibration by multiple-beam interferometry are the subject of several papers now in preparation.

(iii) *Phase Loss Studies by Multiple-beam Interferometry.*—In calibrating surface finish standards a differential phase loss arising from the difference in surface finish structure between the polished and etched portions of the standards was observed and measured. These phase loss effects are of fundamental importance in interferometry and the work is being continued on metal surfaces.

(iv) *Calibration of Vibration Standards by Multiple-beam Interferometry.*—Multiple-beam interference techniques have been applied successfully to vibration studies being done by another group within the Division.

(v) *Flatness of Surfaces by Liquid-surface Interferometry.*—The flatness of steel surfaces and optical flats up to 6 inches in diameter has been determined absolutely by interferometry, using a liquid surface as a natural reference of flatness. This work has made it possible to calibrate in a much more reliable and rapid way than hitherto the flatness of optical flats and steel surfaces of vital importance in the maintenance of standards of length in the Division.

(vi) *Surface Structure and Wringing Studies.*—An investigation into the nature and thickness of wringing films and the surface damage effects on glass and on metals in wringing contact has been started. Preliminary experiments have been done on the magnitude of the tangential and normal forces existing between surfaces when in wringing contact. These surfaces will be examined by multiple-beam interferometry for surface damage of molecular dimensions.

(vii) *Kösters Interferometer.*—The construction of a modified Kösters interferometer is nearing completion and will be used to determine lengths up to 500 mm. by interferometry.

(viii) *Refractive Index of Mica.*—A very accurate determination of the refractive index of mica has been completed and a report is being prepared for publication.

(*e*) *Electronics.*—Work has been done on the development of a capacitance displacement meter, the temperature control of rooms, the development of a photo-electric light transmission comparator, and the control of brilliancy of light sources. In addition, assistance has been given to other Sections in the Division in connexion with electrical and electronic problems.

(i) *Measurement of Displacement by Capacity.*—In the development of a capacitance displacement meter, measurements of changes in the frequency of a stable oscillator have been used to determine dimensional variation. This method is highly sensitive, and, provided the necessary frequency stability can be achieved, small displacements may be measured very conveniently.

An experimental oscillator, stabilized against variations in mains voltage, has been built in which the major frequency-determining components are housed in a chamber maintained at a constant temperature of 50° C., to minimize the effects of temperature change on the frequency of the oscillator. This has enabled the operation of the capacitors and the inductor in the oscillatory circuit to be studied at elevated temperatures.

A second unit measures the change in frequency consequent on change in length of the object being measured. It will be appreciated that the stability required in this unit must necessarily be comparable to that in the oscillator unit. Considerable progress has been made in the development of both the oscillator and indicator units and it is hoped to produce a working equipment in the near future.

(ii) *Photo-electric Light Transmission Comparator.*—A photo-electric light transmission comparator has been developed for use in conjunction with the evaporation and sputtering equipment. The light comparator is built in two parts, namely, a photo-electric cell unit for permanent atttachment to the evaporation equipment and a general-purpose amplifier which may be used separately if desired.

(iii) *Control of Brilliancy of Discharge Lamps.*—A controller to govern the brilliancy of a Krypton lamp has been built. This apparatus incorporates a transductor in which control of lamp current is obtained by the use of low-tension D.C. voltage from a storage battery applied to the control winding of the transductor. Provision has also been made to install a transductor of greater control ratio, controlled by D.C. current from a mains-operated power supply.

(*f*) *Abrasives and Lapping Investigations.*—The work on the grading of fine abrasives for lapping has been continued, using the Grayson settling equipment and a supercentrifuge.

The problem of producing on hardened steel lapped surfaces of sufficiently high quality for interferometric studies has received considerable attention, and a technique has been developed enabling surfaces to be produced which are optically flat and on which the maximum scratch depth is of the order of only one-millionth of an inch.

A technique has been developed for determining the depth of the scratches which will be produced by any abrasive used under specified conditions.

Techniques have also been developed for producing lapped surfaces of good quality on materials such as copper and stainless steel.

(*g*) *Surveying Tapes.*—A considerable amount of work has been done on the temperature of surveying tapes in the field, and much information collected.

Three 100-ft. tapes to be used for setting up a base line by the Surveyor-General's Department have been graduated so that the 100-ft. interval marked on each tape is correct to within five parts in a million.

(*h*) *Measurement of Gears.*—Measurements have been made on a 12-ft. diameter gear hobbed on the large machine at the Bendigo Ordnance Factory. This gear has been examined for evidence of inaccuracies in the machine. Part of this work was the measurement of undulations on the tooth flanks, caused by periodic errors in the motions of the various parts of the hobbing machine. These undulations have been recorded and analysed by a method not hitherto used for undulation records.

Progress has been made in the measurement of hobs and of gears of more normal size.

(*i*) *Test Work.*—(i) *Calibration Service.*—The usual activities of calibration and consultant service for industry have been continued during the year, and numerous inquiries dealt with on matters as diverse as the design of a set of planetary gears, the graduation of carpenters' rules, the accuracy of a jig borer, the setting up of a profile projector, and the care and maintenance of slip gauges.

(ii) *Examination of Machine Tools.*—Work has been done for the Department of Trade and Customs and also for an overseas manufacturer on the examination of precision lathes. A new test has been developed to determine the combined effect of axial float of the spindle and squareness of the surfacing slide.

### 3. MEASUREMENT OF MASS AND ASSOCIATED QUANTITIES.

(*a*) *Primary Standard of Mass.*—The primary standard of mass, a platinum-iridium kilogram, was received during the year. The standard has been determined in terms of the International kilogram by the International Bureau of Weights and Measures and, before being shipped to Australia, was made available to the National Physical Laboratory, England, for inclusion in the decennial intercomparison of the British National Standards.

(*b*) *Standards.*—The reverification of the laboratory standards of mass was begun in May, 1950, and is still proceeding. The results so far are considered very satisfactory.

(*c*) *Instability of Screw Knob Weights.*—Observations were continued on the five sets of rhodium-plated brass screw knob weights and further changes in mass of most of the weights have been detected.

(*d*) *Errors in Balances.*—The investigations have been continued on the discrepancy between theoretical and experimental results mentioned in last year's Report. These indicate that the observed facts are likely to be reconcilable and will draw attention to one criterion of the adjustment of balances for standards work.

(*e*) *Volume-measuring Equipment.*—Requests from industry and from departmental sources for the design of volume-measuring equipment have continued and in most cases a full specification has been supplied.

Methods recommended by two National Laboratories for the use of transfer pipettes, and other suggested time-saving methods, have been critically examined. The results show that any attempt to reduce the time taken to deliver a given volume to below that recommended by the National Laboratories is likely to give rise to substantial errors.

(*f*) *Density-measuring Equipment.*—The hydrostatic balance and its associated equipment were completed and assembled during the year. The equipment, for use in the measurement of densities of solids and liquids, consists of a balance of special design, a temperature-controlled bath containing the working liquid, and an electronic temperature controller. Refrigeration is available should it be desirable to work below ambient temperatures. The temperature controller has been found to work satisfactorily in the range 12° C. to 30° C., and in the neighbourhood of 20° C. it is possible to measure the density of liquids with a precision of one part in 100,000.

(*g*) *Test Work.*—(i) *Calibration Services.*—There has been some increase in this work during the year, mainly due to requirements of the medical profession and of Government Departments.

(ii) *Watch Rating.*—Equipment is being designed for the precise rating of watches, chronometers, and stop watches and it is expected that at least some of this equipment will be in operation during the coming year.

A Dawe watch-rate recorder has been purchased and has proved very valuable in the checking of stop watches. Control is maintained by reference to the frequency standards (quartz clocks) of the Division of Electrotechnology.

### 4. APPLIED MECHANICS.

The co-ordination of testing work involving the examination and calibration of materials-testing machines at their sites, and of instruments at the Laboratory, has been continued. Attention has been given to the development of improved facilities for the determination of physical quantities such as force, pressure, angular speed, stress, strain, and hardness. Some special tests and calibrations have been made for private firms and Government Departments.

An earlier Report mentioned the growing demand from industry for assistance in the measurement of vibration, and in the isolation of delicate instruments from the effects of vibration. The officer of the Section mainly concerned with this work has now returned from overseas and has resumed work in this field.

(*a*) *Co-ordination of Testing.*—As in the past, materials-testing laboratories, machines, and personnel have been examined in New South Wales and Queensland, mainly on behalf of the Services inspection authorities. Instruments received from private firms, Government Departments, and the Services have included pressure gauges, tachometers, portable hardness-testing devices and diamond indenters, rubber durometers, and portable testing machines for various special purposes.

(*b*) *Development of Facilities for Determining Physical Quantities.*—In the examination and calibration of the testing machines and instruments referred to above it is necessary to determine physical quantities such as force, pressure, angular speed, and hardness. Constant attention is given to improving the accuracy and extending the range of equipment available for such determinations, as illustrated by the following items:—

(i) *Force.*—The calibration of materials-testing machines requires the use of portable force-measuring (proving) devices. These devices must in turn be calibrated to an order of accuracy much higher than that of the machines they calibrate. Negotiations are in hand for the supply and installation of a machine in which such proving devices may be calibrated to the desired order of accuracy. This machine will be capable of applying a full load up to 50 tons by means of deadweights.

The development of force-measuring devices employing wire resistance strain gauges has continued. Results of experiments on tension bars and proving loops pointed to the need for investigation of the long-term stability of the gauges. This is now being studied. A four-channel electrical measuring bridge of a special design prepared in co-operation with the Division of Electrotechnology, and a gauge calibrator designed by the Applied Mechanics Section, have been constructed for use in this work.

(ii) *Pressure.*—The accuracy at present attainable in the determination of pressure by means of the conventional dead-weight pressure gauge tester is governed by the accuracy with which the effective diameter of a plunger-cylinder combination may be measured. To facilitate this measurement, a modified form of pressure gauge tester has been designed in which the plunger cylinder combination for a particular range of pressure may be removed completely from the apparatus, thus permitting the cylinder to be placed in a measuring machine in which the internal diameter may be determined to a higher order of accuracy than was possible previously. Construction of this new unit is nearing completion.

(iii) *Angular Speed.*—Apparatus for the calibration of tachometers and other angular-speed measuring devices, which has been in process of development for some years, is now being incorporated into a permanent and self-contained installation, and various accessories provided to facilitate the calibration of tachometers of widely varying types and range.

(iv) *Stress and Strain.*—Apparatus for stress analysis by photo-elasticity which will increase the facilities for stress analysis in the Laboratory is now undergoing assembly and adjustment of the optical components.

(v) *Hardness.*—Arrangements have been initiated for the construction of a machine of N.P.L. design in which penetration hardness tests may be carried out by dead load. Such a machine is needed as a reference machine for the verification of hardness-testing machines used in industry.

A rubber-hardness testing machine designed and constructed at the Laboratory is being modified to give improved accuracy.

(*c*) *Vibration.*—The first phase of a research into the isolation of sensitive measuring apparatus from the effects of small vibrations such as occur in buildings, namely, a systematic search of the available literature, has been completed. It is now necessary to develop methods for measuring extremely small vibratory displacements preparatory to undertaking experimental research into vibration isolation. Two methods of measurement are being investigated at present, one employing optical interference with a stroboscopic light source, the other depending upon electrical capacity change. Preliminary tests indicate both methods to be very promising and a single experimental vibrometer is being constructed to incorporate both methods of detecting vibration. The optical interference elements will enable the pick-up to be calibrated directly in terms of light wave-length. The use of electrical capacity elements will permit the wave-form of vibrations to be observed and will facilitate the design of a compact and easily portable unit.

Assistance given in vibration problems submitted by various bodies has involved measuring the vibration of a building wall due to traffic, the vibration of a jig-boring machine due to operation of a plate-shearing machine in the vicinity, the vibration at a site proposed for an instrument room due to operation of nearby internal combustion engines, and the vibration of a grinding machine due to operation of sheet-metal presses in an adjacent shop.

(*d*) *Test Work.*—In addition to the examination of materials-testing laboratories mentioned above, a number of tests of a more specialized nature have been carried out, including the following:—

(i) *Microhardness.*—In order to show the special requirements for diamond pyramid indenters intended for use in microhardness testing, light load indentations were made and demonstrated at high magnification to an indenter manufacturer.

(ii) *Glass Cutters.*—Endurance tests were made on a number of wheel-type glass cutters on apparatus specially designed for the purpose.

## XXIV. PHYSICS.

### 1. General.

The Division of Physics, which is one of the three Divisions constituting the National Standards Laboratory, is responsible for maintaining the Commonwealth standards of measurement in heat and light, and the primary electrical units of resistance and voltage. As science and industry develop, internationally recognized standards for more and more physical units are found to be required, and greater accuracy is needed in measurements generally and hence in the maintenance of standards. A considerable part of the work of the Division consists in research on the maintenance of standards and on methods of accurate measurement.

The *Weights and Measures (National Standards) Act* 1948 has provided for the dissemination throughout the Commonwealth of uniform units of measurement, based on the standards maintained at the National Standards Laboratory. The problem of defining standards of measurement in the Regulations to this Act in terms acceptable to the law, and at the same time lending themselves to the practical requirements of maintaining those standards in a laboratory, has been given very careful consideration by the Division in collaboration with the other Divisions of the National Standards Laboratory. This problem arises mainly because science and industry now require standards of measurement, as in light, heat, and electricity, which, unlike the standard gram weight or metre length, cannot be locked in a strong room and periodically brought out for inspection or use.

Members of the staff of the Division have continued to assist in the work of the National Association of Testing Authorities, the Standards Association of Australia, and the National Committee on Illumination.

Besides its work on standards, the Division has in progress a number of researches of a more general physical nature. One of these is an investigation of the composition and temperature distribution of the solar atmosphere. This work is complementary to researches in solar physics by the Division of Radiophysics and the Radio Research Board. A spectroheliograph which will take photographs of phenomena such as flares and prominences on the sun's surfaces is being constructed, and will provide data for all three groups working in this field.

A considerable amount of work has been done during the year on the construction of equipment for researches on the properties of matter at very low temperatures.

The group of workers on the physical properties of wool has been mainly engaged in setting up equipment for the measurement of the elastic properties of wool by supersonic techniques.

### 2. HEAT.

This Section maintains the Commonwealth standards of temperature and carries out calibrations of temperature-measuring equipment in terms of these standards. It also undertakes research in the measurement and control of temperature and humidity and in heat problems generally, and gives assistance to industry in these fields. The temperature scale maintained is the "International Temperature Scale", which was adopted in a provisional form by international agreement in 1927 and revised in 1948. The revised scale was adopted during the year and further work has been done to increase the accuracy of measurements. The Section also maintains the standards of viscosity.

Researches reported last year on phenomena associated with natural and artificial production of rain, namely, the initiation of ice crystal formation and the growth of water drops by collision with smaller droplets, have been continued, and some work has been done on the relationship between the size of drops and the temperature at which they freeze on supercooling. Equipment for studying phenomena at temperatures down to within a few degrees above absolute zero is being assembled and preparations for investigations are in hand.

During the year industry has continued to make considerable use of the Laboratory's facilities for calibrating test equipment, particularly devices for measuring temperature. Complete furnace and pyrometric installations in factories and similar establishments have been tested on the site.

(*a*) *Temperature Measurement and Control.*—Many industrial processes and scientific researches require very accurate measurement and control of temperature. For this reason the maintenance of standards of temperature measurement is one of the functions of the National Standards Laboratory.

The ideal scale of temperature is one based on thermodynamic principles, but this is difficult to reproduce accurately in practice. The "International Temperature Scale", which was adopted provisionally in 1927 by international agreement, approximates closely to the ideal scale, but is based on a number of reference points (boiling points and melting points, &c., of specified compounds of high purity), and can accordingly be accurately reproduced by interpolation in any well-equipped laboratory.

Modern scientific research and industrial processes frequently call for a high degree of accuracy in measuring temperatures and consequently in calibrating measuring equipment. To provide for this required increase in accuracy, the Ninth General Conference on Weights and Measures revised the "International Temperature Scale" by international agreement in October, 1948. Details of the changes introduced are to be found in last year's Report.

During the year the Division of Physics has carried out most of the experimental work necessary for the practical adoption of the revised scale. Apparatus has been set up for calibrating temperature-measuring equipment between 0° C. and −196° C., that is, down to somewhat lower temperatures than were defined by the "International Temperature Scale", and a detailed set of tables has been prepared to enable temperatures in this region to be more readily computed from platinum resistance thermometer readings.

Further work on the errors caused by inhomogeneities in thermocouple material has been carried out, and the substandard optical pyrometer used for measuring temperatures above 1063° C. has been recalibrated. One of the basic physical constants of radiation pyrometry is to be re-determined, using this instrument and the optical polarizing device described in last year's Report.

During the year the amount of substandard temperature-measuring equipment submitted for calibration has increased, and a further increase is expected to result from the activities of the National Association of Testing Authorities. About the same number of factory installations were calibrated on the site as in former years. Assistance has been given in solving many problems in producing uniform temperatures and in temperature control and measurement, particularly where unusual techniques or high accuracies are required.

(*b*) *Hygrometry and Moisture Content of Substances.*—The officer chiefly responsible for this field of work is at present abroad, and there is little new to report. Some attention has been given to producing accurately known humidities for test purposes, and advice and assistance have been provided on various problems in humidity measurement and control.

Further work has been carried out on the use of thermal measurements for determining the moisture content of materials such as foundry sands. In this method a temperature rise is observed which is related to the product of specific heat, density, and thermal conductivity of the material; at least two of these increase significantly with moisture content. It seems doubtful whether the uniformity of foundry sands is sufficient to yield reproducible results; but the precision of measurement on individual samples is high, and the method might be useful for other investigations where all the significant factors are under control. One case of possible industrial importance is the relationship between the thermal conductivity of powders and the pressure of the surrounding gas.

(*c*) *Miscellaneous Test Facilities.*—The Heat Section undertakes calibration and testing in a number of fields other than temperature and humidity measurement. There has been some increase in the number of viscometers submitted for calibration and liquids submitted for the measurement of viscosity. Measurements have been made of the coefficients of thermal expansion of various materials, particularly glasses, and advice and assistance given on a number of heat transfer problems.

(*d*) *Precipitation.*—Investigations on the inoculation of supercooled clouds to produce ice crystals and on the growth of drops falling through a mist have been continued. Work has also begun on the effect of time of exposure and drop size on the temperature at which liquid drops freeze. These investigations are complementary to the field investigations undertaken by the Division of Radiophysics, and are reported in more detail in Chapter XXVII, Section 9.

(*e*) *Low-temperature Physics.*—Preliminary tests have been made on the equipment built in the Laboratory for producing temperatures near absolute zero (−273° C.) and for the liquefaction of helium and other gases. Nitrogen has been liquefied (−196° C.) using both nitrogen and helium as the working gases in the equipment; with helium a temperature of about −225° C. was attained. Various modifications and additions to the equipment were found necessary as a result of these tests and are now being made.

Research work at very low temperatures has not previously been carried out in this country. Near the absolute zero of temperature, strange phenomena such as the perfect electrical conductivity of some substances and the super-fluidity of liquid helium appear. These phenomena, when fully explained, may greatly increase our understanding of the physical behaviour of matter at high temperatures. Moreover, certain physical quantities of importance in chemical industry can only be determined from measurements made at very low temperatures, and preparations are being made for such measurements. For basic temperature measurements, a helium gas thermometer has been constructed and calibrated.

A mass spectrometer "leak-detector" of improved sensitivity has been constructed and has proved of great value in detecting leaks in the low-temperature equipment and in vacuum equipment generally. A somewhat similar mass spectrometer has also been constructed for detecting any gaseous impurities in the helium.

The experience gained in low-temperature work has already proved of value to a large establishment fabricating high-quality steel products. The dimensional stability of steel can be improved by low-temperature treatment, and advice has been sought on the design of suitable equipment for this purpose.

### 3. LIGHT.

The work of the Light Section falls into three main fields: photometry, optics, and solar physics.

(*a*) *Photometry.*—(i) *Photometric Standards.*—Among those standards which national standards laboratories are called upon to maintain, photometric standards have been the least satisfactory, for a number of reasons:—

(i) The unit of candle power was based on certain incandescent electric lamps held by three national laboratories and therefore could not be independently established elsewhere;

(ii) Visual photometric measurements have a low degree of accuracy compared with other physical measurements;

(iii) Observers with normal colour vision differ sufficiently among themselves to affect precision photometric measurements seriously.

Consequently the accuracy with which photometric standards and substandards can be compared has never greatly exceeded the accuracy actually needed in commercial and industrial photometry.

This unsatisfactory position has been greatly improved by the international agreement recorded in last year's Report, namely that photometric measurements will in future be based on the light radiated from a source which can be set up from first principles in any laboratory. This source is a black body at the melting point of platinum. The photometric work of the Section will, therefore, be concerned for some time with setting up the new standard of candle power, now termed the "candela", and with improvements in techniques of measurement. The programme of work includes the establishment of substandards for the photometry of fluorescent lamps, and aims at providing precise and reproducible basic standards for science and industry in the whole field of photometry, colorimetry, and spectrophotometry.

The completion of this programme will take some considerable time, owing to shortage of staff and to the growing demands of industry on the photometric laboratory for calibrating equipment and investigating photometric problems.

(ii) *Spectrophotometry.*—The abovementioned variability of the eye's spectral sensitivity has been met in principle by the international adoption of a standard visibility relationship for the average eye; so that it is now possible to employ purely physical instead of visual methods for measuring and comparing the luminous intensities of photometric standards and other light sources. A precision spectrophotometer has been designed for construction in the laboratory workshop. An essential component will be a polarizing photometer, the inherent errors of which have been calculated.

Samples of greasy wool have been examined spectrophotometrically in order to prepare standard samples for the use of the Gordon Institute of Technology, which is investigating the origin of the discolouration of greasy wool and its effect on the buyer's evaluation of the wool.

(iii) *Photoelectric Photometric Comparator.*—In precision photometry, photoelectric cells which have been corrected to give the same spectral response as a standard observer are inherently more sensitive than the eye. A photometer capable of measuring to an accuracy of ± 0.1 per cent. is being designed on this principle. It is expected that the principle will be applicable also to the spectrophotometer mentioned earlier, and to other photometric measurements.

(*b*) *Optics.*—(i) *Design of Optical Instruments.*—A number of instruments for use in the Division and for other organizations have been designed. These include the spectrophotometer referred to above and the birefringent filters mentioned in Chapter XXVIII., Section 4. There have been constant demands on the optics laboratory for the calibration and testing of equipment and the solution of special problems for industry. In the construction of optical components for these purposes and for other Divisions the optical workshop has played an important and essential part.

(ii) *Reflection Microscopes.*—Much interest has been aroused among biological workers by the possibility of using reflection microscope objectives, as designed by Burch in England for use with ultraviolet light. The advantage of reflection objectives lies in their complete achromatism and larger working distance. Microscope objectives using spherical instead of the aspherical surfaces employed by Burch have been constructed in the laboratory with numerical aperture up to 0.85. Prototypes have shown that the performance, although a little below that of aspherical objectives, is sufficient for many purposes.

An ultraviolet microspectrophotometer designed for use with one of these objectives is to be used for cell research in the Division of Animal Health and Production.

(iii) *Optical Design.*—As a result of years of experience with many different computing methods for designing optical systems, the Division has introduced a number of modifications in standard methods. These have been developed into a complete system of trigonometrical ray tracing which requires only four significant figures in the calculations as compared with the normal six. Details of the methods have been prepared for publication.

(iv) *Measurement of the Constants of Lens Systems.*—In the correction of anisikonia, an anomaly of vision arising from inequalities in retinal image sizes, the magnifying properties of spectacle lenses are of special importance. The vertex refractionometer commonly used in optometry enables all the necessary data on spectacle lenses to be obtained, except magnification.

This limitation has been overcome by adding a micrometer eyepiece to the existing type of instrument. A general theory of the modified system has been developed, and enables it to be used in the laboratory for locating the cardinal points of any positive or negative lens system.

(v) *Pressure of Radiation on Bodies in Motion.*—An investigation based on the wave theory of light has been made of the pressure of radiation on bodies in motion, including the case when the radiation traverses a material medium. A quantum mechanical treatment, applicable to the case when no material medium is present, has yielded results identical with those obtained on the basis of wave theory.

### 4. Solar Physics.

In continuation of the studies of solar flares and the solar atmosphere, work has commenced on the construction of a spectroheliograph to obtain cinematograph records of solar phenomena. The instrument will also be used to obtain data for the solar physics programme of the Division of Radiophysics. Details of this work are reported in Chapter XXVIII., Section 4.

### 5. Electrical Standards.

After many years of research, methods have been developed in some of the major standards laboratories abroad for measuring the basic electrical quantities in terms of the primary standards of length, mass, and time. Much work is involved in establishing such methods and maintaining the equipment, and it is not considered necessary to adopt them for maintaining the Commonwealth primary electrical standards of resistance, voltage, and current. These standards are therefore maintained by resistance coils and standard cells, which are compared from time to time with the electrical standards of Great Britain at the National Physical Laboratory, Teddington.

### 6. The Physical Properties of Wool Fibres.

A small group in the Division of Physics is investigating the physical properties of wool fibres with the aim of obtaining a coherent explanation of the behaviour of wool and textiles in manufacture and in use.

Further research has been carried out on the frictional properties of fibres, and work has begun on the measurement by ultrasonic methods of the frictional properties of keratin, the most important constituent of wool. Work has also begun on the relation between the properties of fibres and the properties of yarns. Further details are given in Chapter XV., Section 8.

## XXV. ELECTROTECHNOLOGY.

### 1. General.

The electrical research of the Organization is undertaken within its Division of Electrotechnology. The Organization is also collaborating with the Electricity Supply Association of Australia in encouraging electrical research within the Universities through its Electrical Research Board.

The Division of Electrotechnology forms part of the National Standards Laboratory. It is responsible for maintaining the Commonwealth standards of measurement of electrical units other than the primary standards—the volt and the ohm. In addition to its research on electrical measurements and standards, the Division is investigating the properties of dielectric materials.

The work of the Division during the past year is outlined in Sections 2—7 below. The activities of the Electrical Research Board form the subject of Section 8.

The staff of the Division has continued to play an active part on various technical committees set up by both the Standards Association of Australia and the National Association of Testing Authorities.

The Division has met an increasing demand for measurements from outside bodies, and during the year 68 test reports were issued. Several improvements and extensions were made to the Division's facilities for measurement. A booklet describing the tests normally undertaken and the fees charged is at an advanced stage of preparation, and should be available to the public shortly.

### 2. Direct Current.

The demand for measurements from outside bodies has steadily increased, and the staff concerned have spent almost all their time on calibrating measuring equipment and maintaining the direct-current standards and instruments.

A multi-range sub-standard D.C. instrument for current and voltage measurement has been completed. This instrument, which will be used for check tests on instruments calibrated with a D.C. potentiometer, incorporates a new method of compensation for temperature changes. A double-pole mercury reversing switch, for use in measurements by the potentiometer method, has been constructed.

Several types of imported rubber-insulated electrical cables have been tested at the request of the Department of Trade and Customs.

Apparatus has been set up to measure the relative permittivity and loss factor of dielectrics at frequencies as low as 0.4 c/s. by a bridge method. A simple approximate expression has been found for deducing the loss factor, at even lower frequencies, from the current that flows after the sudden application of a direct voltage. These techniques are of considerable value in the experimental study of dielectric aftereffect mentioned in Section 6.

### 3. Power Frequency.

The sine wave alternator set, which supplies electricity for the accurate measurement of power, voltage, and current, is working satisfactorily with temporary circuits for controlling frequency and voltage. The installation of the control circuits in more permanent form is in progress.

Step-up potential transformers have been made which extend the range of the electrostatic voltmeter down to one-eighth of a volt. It is now possible to measure any voltage, from one-eighth of a volt to 6,000 volts, with an accuracy of the order of 0.01 per cent. by using either step-up transformers or resistive potential dividers in conjunction with the electrostatic voltmeter.

The dynamometer wattmeter, used for calibrating wattmeters and watt-hour meters, has been fitted with new scales following the replacement of its current and potential coils. Its accuracy has been checked on all ranges, and the instrument is ready for use. A timing unit for use in calibrating watt-hour meters has been designed, and is being constructed in the workshop.

Current transformers are normally tested at the Laboratory by comparison with "standard" transformers, the errors of which must therefore be determined by some independent means. A new and simple "build-up" method which has been developed for calibrating these standard transformers requires very little additional equipment, and avoids the necessity for setting up more expensive and elaborate measuring equipment. Comprehensive tests have shown that this method is entirely satisfactory.

Although not yet in its final form, the voltage transformer testing equipment has been used extensively, not only for testing and calibrating transformers, but also for capacitance and power factor measurements. A small auxiliary transformer has been made, for use n association with a 240-V. to 40-kV. power transormer operated in reverse. The combination forms a multi-range potential transformer of high accuracy, which will be used for general measuring and check esting work.

Limited facilities now exist for testing at high voltages up to 100-kV. A special form of wire-wound resistor, compensated for resistance change due to temperature rise, has been developed for use in a 100-kV. voltmeter multiplier.

The power frequency section is now able to meet any demands likely to be made on it for the accurate measurement of power, voltage, or current at frequencies between 20 and 60 c/s.

### 4. Audio and Radio Frequency.

(*a*) *Impedance Measurement.*—As a preliminary to the design of permanent test equipment, some time was spent in evaluating new methods for measuring impedance at audio frequencies. In one method, the use of transformers as radio devices in bridge circuits was investigated. Bridge circuits using such transformers are simpler both to construct and to operate than bridges using Wagner earths, and are capable of the same precision. As it has been possible to produce satisfactory transformers with ratio and phase angle errors of less than 1 part in $10^5$, the design of a transformer bridge for measuring capacitance is in hand. The comparison of impedances by means of a null-reading differential voltmeter has also been investigated. An instrument based on this principle for measuring impedance has been constructed. This method is being developed further for measuring capacitance with the highest accuracy in terms of resistance and frequency.

(*b*) *Dielectric Measurements.*—Equipment has been developed for maintaining the temperature of dielectric specimens during measurement at any value within the range $-50°$ C. to $+70°$ C. Constant-temperature measurements can be made at frequencies from 50 kc/s. to 50 Mc/s., and the device is also incorporated in new apparatus developed for dielectric measurements at 24,000 Mc/s.

(*c*) *Frequency Measurement.*—The Commonwealth frequency standard has been in operation for about a year. It is rated by sending out daily signals to the Commonwealth Observatory at Mount Stromlo, and by the reception of time signals from Station WWV of the National Bureau of Standards. It is believed that the frequency of this standard is known to 1 part in $10^8$. Increasing use is being made of the standard both within the Laboratory and by outside organizations.

(*d*) *Noise Generators.*—For the absolute determination of the sensitivity of receivers, particularly in the microwave region, random noise generators are of fundamental importance, and a small group has been set up to develop suitable noise sources. In particular, a mercury discharge lamp is being investigated as a noise generator at 3,000 Mc/s.

(*e*) *Microwave Spectroscopy.*—A microwave spectroscope has been constructed for fundamental and applied studies of the spectral absorption lines of polar molecules in the gaseous state. The first gas chosen for investigation is nitrosyl chloride which, from theoretical considerations, is expected to have absorption lines in the microwave region.

Microwave absorption lines are, in most cases, due to transitions between rotational energy levels of the molecule which are determined by its principal moments of inertia. A method has been developed by which these moments can be readily calculated from a knowledge of the atomic masses and their mutual distances in the molecule. This has greatly simplified calculation, compared with previous methods in which the position of the centre of mass of the molecule had to be determined in addition.

Klystron oscillators are very sensitive to power supply variations, and the more precise microwave measurements require these fluctuations to be a minimum. To meet this need, a specially filtered and stabilized high-tension supply has been developed with an output voltage that is continuously adjustable from 1,450 to 1,950 volts, and contains less than one millivolt of ripple voltage.

### 5. Magnetic Measurements.

In tests on magnetic materials with alternating magnetization, a rotating commutator type of rectifier voltmeter is normally used when high accuracy is required. This type of rectifier, however, requires constant attention and frequent adjustment for satisfactory results. It has been found that efficient and reliable rectification can be obtained from a synchronous high-speed polarized relay, which also enables the upper limit of frequency to be extended considerably. A relay of this type has been incorporated in the equipment for measuring flux density.

Promising results have been obtained in experiments on measuring static fields of low intensity by a mu-metal magnetometer method, and this technique is being modified for measuring high-intensity fields.

### 6. Dielectric Investigations.

The main line of work for the past few years has been the investigation of the dielectric properties of materials, with particular emphasis on the various possible mechanisms of dielectric loss. The materials chosen for this work were long-chain hydrocarbons and their polar derivatives, mainly because of their comparatively simple molecular and crystal structure. Considerable progress has been made in relating the structure of those compounds to their dielectric properties (see below).

(*a*) *Dielectric After-effect.*—This effect in capacitors, which is also known as charge "soaking", is characterized by an anomalous charging current which continues after the normal charging current has ceased. It has been found that this effect can be produced in paraffin wax by the addition of small quantities of liquid alcohols and also by prolonged heating of the wax. The investigation is being continued using the pure hydrocarbon docosane instead of paraffin wax, which is a mixture of hydrocarbons of different chain-lengths.

(*b*) *Dielectric Properties of Solid Alcohols.*—As reported last year, preliminary investigations had shown unexpectedly high dielectric absorption to occur in solid secondary alcohols. This phenomenon has now been investigated further in pure alcohols and in mixtures of alcohols both with pure hydrocarbons and with paraffin wax. Symmetrical secondary alcohols were chosen as the first type to be investigated in detail, and the absorption has been shown to depend greatly on the method of solidification of the compound, the chain-length of the alcohol, and the time interval between preparing the sample and measuring it.

A theory has been developed attributing the high dielectric absorption to the presence of long chains of hydroxyl groups linked by short-range hydrogen bonds. The other experimental features described above are then readily accounted for by the various influences of van der Waals' forces, thermal energy, and hydrogen bonding under different conditions of formation of the solid state.

A series of measurements on primary and non-symmetrical secondary alcohols, both in the pure state and in solution, exhibits similar characteristics and gives further support to this theory.

(*c*) *High-frequency Absorption in Methyl Esters.*—While working overseas on a C.S.I.R.O. studentship, an officer of the Division demonstrated that the ester, methyl palmitate, had two regions of absorption at high frequencies. This is of considerable fundamental interest and further experiments have been conducted to elucidate the effect. Other methyl esters of different chain-lengths have been measured over the frequency range 90 kc/s. to 24,000 Mc/s. and at temperatures ranging from −20° C. to +25° C. The results suggest that the two absorption regions are due to separate relaxation phenomena and also indicate the presence of an additional absorption region at frequencies above the range of the present measuring equipment.

(*d*) *Theoretical Investigations.*—Following last year's work on sulphur dioxide, the theory of the static dielectric constant of substances with non-spherical molecules has been extended to deal with anisotropies of shape and polarizability separately. A new method of calculation has been developed to cover the case of pure polar liquids, as compared with previous methods which covered only solutions in non-polar media.

(*e*) *Influence of Electrodes on Dielectric Measurements.*—Dielectric materials in powder form have been pressed into disks and at the time of moulding, electrodes of aluminium foil have been pressed on to the surfaces of the disks. Improved electrodes have resulted from evacuating the die to a pressure of approximately 25 mm. of mercury while the disks are being moulded. Conductivity measurements on such samples at direct current and frequencies below 50 c/s. agree substantially with those obtained with mercury electrodes.

### 7. Vacuum Electronics.

Following the development last year of an experimental electron beam tube for counting in the scale of five, the Division has produced a tube of improved design for counting in the decimal system, which it is hoped to adapt for commercial production. Details of this work are given in Chapter XXX., Section 4.

### 8. Electrical Research Board.

The Electrical Research Board was established in 1945 to advise the Organization on matters connected with research on electricity and magnetism. It is representative of the Commonwealth Scientific and Industrial Research Organization, the Universities, and the Electricity Supply Association of Australia, and its functions are analogous to those of the Radio Research Board. The Electricity Supply Association of Australia is actively interested in the work of the Board, and its members have agreed to contribute funds totalling £5,000 per annum to permit electrical research to be fostered in the Universities.

In the Universities of Adelaide, Melbourne, and Tasmania, work supported by the Board has been continued on electrical simulating networks for power supply systems, power system stability studies using model networks, and electrical transient investigations. Two papers covering the last-mentioned investigations have been published.

Work has been initiated in the University of Sydney on the high-voltage direct-current generation and distribution of power, on a study of the current density at the cathode of an arc, and on electro-magetic waves in low-pressure electrical discharges subject to magnetic fields.

## XXVI. RADIOPHYSICS.

### 1. General.

The work of the Organization on problems relating to the propagation and detection of radio waves, and on the application of radio techniques to investigations in other fields, is carried out mainly by its Division of Radiophysics. Further research, mostly relating to radio transmission problems, is undertaken by the Organization's Radio Research Board in collaboration with the Postmaster-General's Department and several Australian universities.

*Division of Radiophysics.*—The work upon which the Division of Radiophysics has been engaged during the past year has been a continuation and extension of that detailed in last year's Report. It may be briefly summarized as follows:—

(i) In the field of radio astronomy, knowledge and understanding of the radio-frequency radiation which reaches the Earth from the Sun, from radio stars, and from the galaxy have been advanced by further successful observations.

(ii) The special advantages which radar methods of observation bring to the study of rain and cloud physics have been exploited. Advancement has been made in our understanding of the processes by which natural rain occurs and this knowledge has been applied to work already in hand on methods of producing rain by artificial means. Further information has been obtained on the effects produced by seeding cloud of various types with dry ice and silver iodide.

(iii) A new programme of radio and radar aids to navigation has been introduced in which the two main items are microwave direction finding and relay radar. The microwave direction finding system, as its name implies, operates in the microwave region and has been designed, flight tested, and demonstrated to the Department of Civil Aviation, airline companies, and the Royal Australian Air Force. The Department of Civil Aviation is sufficiently interested in this device to have arranged for the construction of a number of units, to be installed in the aircraft of airline companies and given trials under operating conditions on a commercial air route.

The other achievement in this field has been the successful demonstration of light-weight equipment (relay radar) by means of which a replica of the display seen on a high-powered ground-based radar set is relayed to an aircraft. With such a device the pilot is able to "see" his own aircraft in relation to the radar set, to other aircraft, and to hills, mountain ranges, and other navigational hazards within range.

Some further work, mainly in a consultative capacity, has been carried out on distance measuring equipment (one of the Division's earlier navigational projects) following its adoption and large-scale manufacture for use on air routes throughout Australia.

(iv) Progress has been made in the adaptation of existing computing techniques to the special needs of scientific computing, and in the development of an electronic calculator which has been designed to deal expeditiously with the particular computing needs arising within the Division. This work is described in Chapter XXX, Section 4 (*a*)-(*d*).

The work of the Division is outlined in Sections 2-9 below.

*Radio Research Board.*—The Radio Research Board has continued its investigations of physical and electrical processes in the upper atmosphere of the Earth and their effects on radio propagation.

The Chairman and scientific officers of the Board have taken an active part in the establishment, by the Australian National Research Council, of an Australian National Committee of Radio Science to co-ordinate scientific radio investigations in Australia and report the Union Radio-Scientifique Internationale J.R.S.I.), which co-ordinates radio research on a orld-wide basis. A successful conference was ganized by the Committee to select papers for bmission to the U.R.S.I. Of 32 papers presented, 10 ealt with work of the Radio Research Board.

The *Journal of Geophysical Research* in the United tates of America requested permission to publish a mmarized version of the proceedings, and this has een granted.

The work of the Board is outlined in Section 0-12 below.

### 2. Radio Astronomy.

The great strides made by radio techniques over the ast ten years have made it possible for such methods be used in astronomical research. We can now etect not only the light and heat radiations reaching s from the heavenly bodies, but also the longer radio aves. A whole class of stars, many of them invisible y optical means but easily detected by their radio manations, has thus been thrown open to investigation. n addition, these techniques provide a valuable new eans of studying already known bodies such as the un, and the results may well have important practical mplications in fields such as meteorology and radio ransmission.

The work of the Division of Radiophysics in radio stronomy is described in Chapter XXVIII., Sections and 5.

### 3. Lunar Observations.

The analysis of the moon-echo experiments described ast year has been completed. The main interest in the xperiment was in obtaining information about propagation conditions between the Earth and the Moon, particularly in the upper part of the ionosphere, which annot be examined by conventional ionosphere-echo experiments. The main result obtained was that the bservations did not conform with the generally-accepted model of the ionosphere, which is more difficult to penetrate than theory suggests.

### 4. Thermal Radiation from the Ionosphere.

The major components of terrestrial radio noise arise from natural sources, such as lightning, and man-made sources, such as electrical machinery, but there should also be a background due to thermal radiation from the ionized gases of the ionosphere. The expected level is very low, about 0.001 $\mu$V/m. in a bandwidth of one kilocycle, and is far below reported results of measurements, which are about 0.1 to 1 $\mu$V/m.

Careful measurements were made during the day on a frequency of 2 Mc/s., under conditions as free as possible from the effects of thunderstorms and electrical machinery, and this very low level was found to exist on quiet days. The measurements can be interpreted as giving a direct measure of the maximum temperature in the absorbing portion of the ionosphere. This was found to be about equal to ground-level temperature, as was expected. It is hoped that this new method of obtaining information about the ionosphere can be used to study changes occurring within it, but the technique is upset by even slight interference from other sources. The thermal component can certainly be recognized, but further observations are required to determine whether the technique can be used systematically.

Ionospheric investigations undertaken by the Radio Research Board are described in Sections 10-12 below.

### 5. Mathematical Physics.

The Mathematical Physics group has been studying numerical processes and their large-scale application to problems arising within the Division and elsewhere in the Organization. Various units of the high-speed electronic computer under construction in the Division have been assembled and tested.

This work is described in more detail in Chapter XXX, Section 4 (*a*)-(*d*).

### 6. Radio Meteorology.

Radio and radar waves are affected by meteorological conditions in a number of ways; "radio meteorology" is the name given to that field in which a study of these effects may be of assistance in meteorology. For example, radio waves of very short wavelength are reflected or scattered appreciably by raindrops and ice and snow particles. Radio methods can, therefore, provide a valuable means of studying such problems as the formation of both natural and artificially induced rain. There are a number of other properties of clouds to which radio or electrical methods of investigation are applicable, for example vertical air velocity, cloud water content, cloud temperature, and drop size.

The present programme of the Division may be divided into four parts, dealing respectively with rain physics, artificial rain formation, cloud physics, and upper air investigations. Details are given in Chapter XXVII, Sections 7, 8, 10, and 11.

### 7. Radio Aids to Navigation.

Promising results have been obtained with the microwave direction-finding system mentioned briefly last year, and a new project also showing considerable promise has been initiated. This is the relaying to an aircraft of the radar display seen on a high-power ground radar.

Although last year's report indicated that the two major aids to civil aviation (distance measuring equipment and multiple track range) on which the Division had been working since the end of the war were then practically completed, some further work has since been undertaken on these systems, in view of the facts that D.M.E. has been adopted for use on an extensive scale on commercial air routes throughout Australia and that the Royal Air Force is interested in its possible applications in Great Britain.

(*a*) *Microwave Navigation.*—The best and safest method of navigation for aircraft, or for ships in coastal or confined waters, is unquestionably the use of ground markers or lights to define the exact course to be followed, to indicate positions along the route, and to mark out hazards to be avoided. A serious disadvantage of visual methods, however, is that in bad weather, when guidance is most needed, they may be of little or no assistance. A microwave system has been developed which uses radio transmitters as beacons in place of ground markers or lights, and a receiver and display system in the aircraft (or ship), which enables the pilot or navigator to "see" these beacons in their correct relation to himself under all conditions of weather or visibility, just as he would see visual markers on a clear day or night.

The experimental equipment has now been built, and extensive flight tests carried out in the vicinity of Sydney to investigate its use for such purposes as homing, route flying, collision prevention, and the execution of "holding" and "approach" procedures. Its application to marine navigation is equally obvious and arrangements for similar tests in coastal waters are being made. Demonstrations of the device have been given to the Department of Civil Aviation, the airline companies, and the Royal Australian Air Force. The Department of Civil Aviation is interested in having a number of fully-engineered models constructed, so that trial installations may be made in the aircraft of an operating company and experience of the system gained under normal conditions of commercial flying. Suitable designs for both the airborne and ground installations are therefore being finalized.

(*b*) *Relay Radar.*—The Division had previously developed techniques for reproducing, at a remote point, the display seen on a radar set; and these have now been applied to the transmission to an aircraft of a radar picture as it appears on a high-power ground radar set.

Experimental equipment for this purpose has been built and installed in an aircraft, and flight tests carried out. The ground radar set used for the purpose was the LW/AWH Mark II, which was developed by the Division for the Royal Australian Air Force and is installed and operating at George's Heights, near Sydney. The flight tests revealed at once that the method showed great promise as a navigational aid. The display in the aircraft allows the pilot to "see" the position of his own aircraft in relation to the ground radar, to any other aircraft within range (100 miles), and also to navigational hazards such as hills and mountain ranges, which appear as "ground echoes" on the display. The system, therefore, provides for point-to-point navigation over a wide area, position-fixing, the flying of predetermined tracks and other traffic patterns, and avoiding collision. Further, the airborne equipment is nothing more than a receiver and a display, and hence can readily be used by light aircraft as well as by the larger commercial types.

(*c*) *Distance Measuring Equipment.*—The need for a simple means of providing a number of separate channels for D.M.E. led to a study of the use of multiple-pulse transmissions. The use of pulse-coded transmissions enables a number of beacons to work safely on the same wavelength, the separation in time of the several pulses in a group being characteristic of a given transmission or channel. This work required some modification to the design of the receiver. The necessary models were built and intensive flight tests were made, particularly to find out whether false channels could be formed by echoes from the surrounding terrain. As a result of this work suitable techniques have been established for a reliable double-pulse transmission system, which is capable of providing twelve or more channels on any one wavelength.

Following the adoption of D.M.E. by the Department of Civil Aviation for installation in Australian airlines, much preliminary work has had to be done before this equipment could be produced in quantity in Australia. Continuous liaison has been necessary with the Department of Civil Aviation and, in matters affecting the design of the system, with the manufacturers. A number of engineers and technicians has been trained to operate and maintain the equipment, and six "production prototypes" of the airborne equipment were built and tested so that the Department of Civil Aviation and the airline companies could obtain early operating experience with the system. Accelerated life tests have also been carried out to obtain guidance on the performance of the equipment in actual service.

During the year the Air Ministry, Great Britain, requested the loan of airborne receivers and a ground beacon, so that operational tests of the D.M.E. system might be carried out by Fighter Command of the Royal Air Force. An officer of the Division was sent to England to supervise the installation, train personnel in its use, and be present at the initial tests. The Australian Multiple Track Range (M.T.R.) equipment which had previously been made available for use by R.A.F. Transport Command in Great Britain was at the same time taken over by Fighter Command and used in these tests.

### 8. MEASUREMENTS AND STANDARDS.

The Division's Test Room has been responsible for regularly calibrating and maintaining the wide range of radio and electrical testing and measuring instruments in use throughout the Division. The following investigations have also been carried out.

(*a*) *Germanium Crystals (Transistors).*—A number of germanium crystal transistors have been tested as diodes and triodes. Test equipment enabling the electrical characteristics of these transistors to be readily derived has been constructed, and they have been incorporated in several experimental oscillators and amplifiers whose possible use in the work of the Division will be investigated.

(*b*) *Water Content Meter.*—Changes in the electrical properties of various substances which take place as their water content and degree of purity vary have been examined. This work provided the necessary background for the design of a cloud water content meter which has been used in cloud investigations.

(*c*) *Quartz Crystal Clocks.*—A portable crystal-controlled clock, consisting of a high-frequency phonic motor driven directly from a 4 kc/s. quartz crystal, has been developed and its construction is well advanced.

### 9. UPPER AIR INVESTIGATIONS.

This work, which was mentioned in Section 6 above, is directed towards developing radar techniques for mapping upper air wind patterns (above 30,000 feet), which are of increasing importance in civil and military aviation. The use of homing gliders carrying recording instruments is also being investigated. Details are given in Chapter XXVII., Section 11.

### 10. TRAVELLING IONOSPHERIC DISTURBANCES.

Winds and movements in the upper atmosphere have aroused particular interest of recent years, not only from the theoretical viewpoint, but also because of their possible importance in meteorology, and their direct influence on high-flying aircraft and missiles. The detection of horizontal movements in the ionosphere by means of radio is a comparatively recent development, and in this field the Radio Research Board is doing pioneering work, particularly as regards the upper reflecting region known as the F region. The Sydney Section in the Electrical Engineering Department of the University of Sydney has built special equipment for this purpose and has set up an observing system, including two field stations near Sydney operated from the laboratory at the University.

These observations, extending over two years, have shown that the disturbances at a height about 150 miles above the earth travel with a speed of from 5 to 8 miles a minute, going in a north-easterly direction in winter and in a south-easterly direction in summer. A paper describing this work was recently read before the Royal Society and will be published shortly.

Theoretical considerations suggest that the disturbances are due to the occurrence of cellular waves in the atmosphere, borne by winds of the order of velocity observed. A paper putting forward this theory as part of a more general discussion of cellular waves occurring in the atmosphere was recently published by the Royal Society.

Movements are also being observed in the E region about 80 miles above the earth. They are detected on the Sydney system, and also by observations of sporadic signals from radio beacons and amateur transmissions in circumstances where signals would not normally be received.

A group at the University of Queensland in Brisbane, making somewhat similar studies in collaboration with the Radio Research Board, has detected horizontal movements in the F region at night, and observations are also being made at the University of Western Australia in Perth.

This work is being actively pursued and extended, nce it is considered that, in addition to its immediate lue in radio propagation studies, it will contribute ry substantially to our knowledge of upper atmohere circulations.

### 11. Radio Observations in the Antarctic.

The Radio Research Board has collaborated with e Australian National Antarctic Research Expedition setting up equipment for radio investigations on Macquarie Island. A variable-frequency ionosphere ecorder which was made available by the Ionospheric rediction Service of the Commonwealth Observatory as recently installed on the island and is yielding esults which promise to be of great interest. To urther this work the Board maintains regular radio ommunication with the island.

The Sydney laboratory has constructed a new improved type of ionosphere recorder for its own work, nd is assisting in the construction of a modified form f this to be taken to the Antarctic continent with the Norwegian-British-Swedish Antarctic Expedition.

### 12. Effects of Solar Activity on the Ionosphere and the Earth's Magnetic Field.

It is well known that many of the irregular variaions in the ionosphere and in the magnetic field of he Earth are intimately linked, and that both are due initially to bursts of radiation from the Sun. Many theories have been put forward in an attempt to explain the resulting processes in the Earth's atmosphere, but so far none of them has been able to explain all the observed results satisfactorily. Theoretical investigations by officers of the Radio Research Board have now evolved a theory which promises to explain many of the apparent anomalies in the radio and magnetic effects, and also the occurrence of auroras.

The origins, incidence, and effects of solar flares are under investigation both in the Division of Radiophysics and in the Division of Physics (*see* Chapter XXVIII., Sections 2 and 4).

## XXVII. METEOROLOGICAL PHYSICS.

### 1. General.

Following discussions with the Commonwealth Meteorological Bureau, the Organization (then the Council for Scientific and Industrial Research) decided in 1946 to set up a Section of Meteorological Physics. It was recognized that a more detailed knowledge of the physical phenomena occurring in the atmosphere is a matter of first importance to a primary producing country such as Australia. The Section, which is located at Highett, Victoria, has accordingly devoted itself to fundamental studies of these basic phenomena. Its work is described in Sections 2-6 of this Chapter (*see* also Chapter XXX., Section 4 (*f*)).

The Division of Radiophysics has continued its work on the physics of rain formation and the artificial production of rain, and has extended its investigations to include studies of the general properties of clouds and the conditions existing within them (*see* Sections 7, 8, and 10). Laboratory investigations relating to the rain physics work have been undertaken by the Division of Physics (Section 9).

The Division of Radiophysics is also developing radar and other techniques for mapping upper-air wind patterns (*see* Section 11).

Statistical work for determining the expectation of monthly rainfall in South Australia is proceeding in the Section of Mathematical Statistics (*see* Section 12).

*Section of Meteorological Physics.*—This Section was formed for the purpose of making a basic study of the physics of atmospheric processes. The possible scope of inquiry is wide. Comparative studies of atmospheric conditions occurring simultaneously all over the world might be undertaken in analysing changes occurring from day to day (synoptic meteorology), week to week (weather trends), or decade to decade (climatic trends). On a smaller scale there are problems such as the mechanics and behaviour of individual storms, cloud, rain, fog, &c.; and investigations may narrow down to the most minute studies of the differences in temperature, humidity, wind, &c., which occur in and around crops and so go to determine the welfare of Australian primary industries.

The initial programme of the Section, which has now been successfully launched, comprises a selection of these problems at a fundamental level. The Section is not immediately concerned with forecasting the weather, but it is generally agreed that any substantial improvement in accuracy, or extension in time, of forecasts can come only from basic studies such as those on which the Section is engaged. Likewise, the successful use of any means of weather control, such as fog dispersal, frost prevention, and the methods for artificial rain stimulation under investigation in the Division of Radiophysics, in the last resort must depend on the fundamental studies upon which they are based.

### 2. Dynamical Meteorology.

The Section has continued its investigations into the structure of disturbances in the mean zonal flow of the atmosphere, and of the factors influencing the development and movement of these perturbations, which are the immediate cause of the physical variations in weather.

The task of studying tropical cyclones raises the difficulty of obtaining a network of observations within them, since they are of relatively small size and are born and mature at sea. The development of a new physical parameter, the energy ratio, which can be measured from surface observations at one place, promises to mitigate this difficulty. The energy ratio is that of the kinetic energy of the wind to the potential-energy deficit, as indicated by the fall in pressure. Theoretical work indicates that the ratio should progressively decrease through both the maturing and decaying phases of the cyclone, and that its distribution around and in the cyclone should be correlated with the rainfall pattern and the direction and speed of motion of the storm. These indications are supported by such data as are available, and there is promise that a practical tool of considerable value will emerge from these studies.

The friction of the wind on the Earth's surface and the internal friction of the atmosphere exert strong dissipative influences, and the sustenance of a depression or anticyclone requires a suitable distribution of energy sources and sinks; an overweight of one or other determines the growth or decline of the system. Efforts are being made to formulate the source-sink intensities in terms of measurable quantities, and to apply the results to the problems of development and movement of pressure systems.

An important step in modern analysis and forecasting is the assessment of horizontal convergence and divergence in the upper-wind field. The possibility of accurate objective determination of convergence and divergence has been examined and found to be beyond the present accuracy of upper-wind measurements. Analysts from the Commonwealth Meteorological Branch and from England, New Zealand, and the United States co-operated in the experiment.

For earlier work in the field of dynamical meteorology the Officer-in-charge was awarded the Buchan Prize of the Royal Meteorological Society for "work published by the Society within the years 1944-48, inclusive, adjudged to contain the most important original contributions to meteorology".

### 3. GENERAL CIRCULATION AND HEAT BALANCE.

Countries of the northern hemisphere have followed the lead set by Australia in studying these large-scale problems by the method of transport, as described in previous Reports. The most important features of the general circulation are an equatorial zone where the mean surface wind has an easterly component and a temperate zone where it has a westerly component. The strengths of the circulations in these zones fluctuate markedly over periods of from 5 to 30 days, with accompanying broad changes of weather type within the zones. The problems concerned with these changes resolve themselves, fundamentally, in terms of the momentum and energy exchange between the zones. During the last year the efforts of the Section in this field have concentrated on assembling and interpreting world-wide upper air data from the latitudes (30-35°) which constitute the boundary between the zones; and this has led to a study of the nature and magnitude of the physical interactions between the two circulations.

The basic object of the work is a better quantitative understanding of the physical control of the climate of different latitudes. An immediate problem is the nature and cause of the breakdown of periods of strong zonal circulation, and the relatively regular weather sequences which accompany them, into the periods of weak circulation and more varied weather type with which they alternate. A theory of how this breakdown occurs has been advanced, and will be kept continuously under review as more regular and extensive upper-air observations become available.

### 4. MICROMETEOROLOGY.

In the study of micrometeorology also, the Section is concentrating on problems of fundamental interest, but the knowledge so gained and some of the instruments developed should prove of wide use in the pursuit of agriculture in Australia. Micrometeorology is concerned with the detailed structure of conditions and the nature of physical processes occurring in the layers of air next to the ground; despite its economic importance the subject has received little attention in this country. During the last year, progress has been made in the development of instruments and techniques and field work has begun at the meteorological field station at Edithvale, Victoria; the completion of the instrument tower will allow the investigations to be extended to embrace the lowest 90 feet of atmosphere.

The fundamental measurements required are the upward transportation by turbulence of heat, moisture, and momentum. The last is equivalent to the aerodynamic drag of the wind by the earth's surface; and the others represent ultimate sources of atmospheric energy and provide measurements of the extent to which the atmosphere is modified by contact with the earth's surface, leading to the formation of air masses and to most of the major manifestations of weather. The transports are controlling factors in the formation of fog, frost, dew, and other surface phenomena, in atmospheric pollution, and in radio and radar propagation.

Preliminary developments and measurements have involved the simultaneous recording of temperature, humidity, and horizontal and vertical wind components on a fine enough scale to reveal all the fluctuations of physical importance. All the elements show a highly complex structure which varies considerably under different conditions. Interpretation of the results has allowed the turbulent transfer of heat and evaporation from a natural surface to be determined, in a limited number of cases so far, by a method which is free from objection provided that the records are sufficiently sensitive. This latter point is under investigation. It is believed that the measurements by this technique constitute the first absolute determinations of natural heat transfer and evaporation. The present technique is laborious and efforts will be made to simplify it for extensive field use; even if this proves impossible it will remain as the standard method against which the simpler, but inferential, methods now in use can be compared. The present field work will be extended to all conditions, and the relations studied between the transport and the strong gradients of temperature, humidity, and wind which occur near the ground.

A by-product of this work has been the development of equipment for registering the fine structure of humidity which may have applications in agriculture and other industries and in fields of scientific inquiry.

A separate study is being made of the extent to which the temperature fluctuations fall off with height above ground, and of the correlations between fluctuations at different levels. This may be extended later to other properties, and is expected to yield basic information on the nature of the fine-grained turbulence.

An instrument providing a continuous record of the heat flow into the ground has been developed and is now in operation.

### 5. FROST PREVENTION.

In most Australian fruit-growing districts frost occurs only on clear nights, as a result of outgoing radiation. The intense cooling is confined to the lowest layers, while at 100 feet the air remains some 10° F. warmer. It is possible to warm the air at fruit level by sucking down this warmer air with a 20-ft. or 30-ft. diameter fan driven by a 10-h.p. motor.

The results of trials continued during the past winter, and of parallel tests in England inspired by the Australian work, have now made it possible to predict the extent and amount of air-warming brought about by this fan under a given set of conditions. The benefit is considered to be marginal for citrus. It is thought that some additional benefit may accrue from a fan with a tilted axis, which combines the direct suction action with a more thorough mixing of the air and so reduces the buoyancy of the air brought down. This buoyancy and the limited range of the warmed air (which may also be increased by tilt) were thought to set a limit to the efficiency of the original design. A tilting fan has been constructed and installed for trials at Griffith during the coming winter. A duplicate layout of temperature-measuring equipment has been constructed to allow these trials to proceed in parallel with tests of the more powerful but more expensive American type of frost-prevention wind machine.

Fine thermocouples in hypodermic needles have been designed to record the temperatures in various portions of the fruit, so that the relation between fruit and air temperatures may be included in the biological studies of the frost damage problem.

### 6. PHYSICAL CLIMATOLOGY.

(*a*) *Climatic Trends.*—There is to-day general recognition of a current change in world climate, which is reflected in the northern hemisphere in a eneral recession of the glaciers and an upward trend n mean winter temperature in the temperate zone. tudies of mean temperature in Australia have so ar revealed no such trend, but mean temperature is ot the sole indicator of climate. The nature of the eneral circulation in this region suggested that ppreciable changes in climate might be manifest in lements other than mean temperature, and investigaions to test this view have begun. The evidence ssembled so far indicates that over the last 60 years, here has been a downward trend in daily maximum emperatures in summer, and a marked increase in ummer rainfall in Victoria and South Australia. These would be consistent with an increasing strength of the zonal circulation.

(*b*) *Evaporation Survey.*—Surveys of evaporation, or potential evaporation, over the Australian continent are an essential guide in problems of land use and rural development. Previous surveys and studies of the water loss from evaporation tanks in Australia have made no allowance for the effect of wind speed, which must exert a considerable controlling influence, and investigations undertaken with this factor in mind show promise of overcoming certain anomalies in the results of earlier work.

(*c*) *Wind in Australian Cities.*—One disadvantage of climatic statistics is the impossibility of securing representative values of wind, especially in built-up areas, since the conditions of exposure of instruments cannot be standardized. A way around this difficulty has been devised, by comparing the recorded "station" wind with wind-speed measurements from balloons at 2,000 feet, where the influence of buildings and contours is relatively small. Correction factors for the observatory site in each capital city are now available. These factors, adjusted to allow for the normal variation of wind with height in the surface layers, have been applied by the Government Departments concerned to questions of the proper siting, design, and natural ventilation of new factory buildings in city areas.

## 7. NATURAL RAIN FORMATION.

Two types of natural rain can now be distinguished. One is due to the well-established Bergeron process which involves the initial appearance of ice crystals, and the second results from coalescence of the cloud droplets without the intervention of ice crystals at any stage. Radar techniques offer unique advantages for detailed study of both these phenomena, and are being applied in several ways by the Division of Radiophysics.

(*a*) *Airborne Observations.*—Airborne observations of natural rain are made from an aircraft fitted with a 10-cm. radar set together with the necessary equipment for recording temperature, pressure, &c. With this radar a picture is obtained in which the aircraft itself appears at the centre, the ground as a horizontal band at the appropriate distance below the aircraft, and rain areas as "echoes" in their correct relation to the aircraft either to port or starboard, above or below. It is thus possible first to locate a rain-bearing cloud, and then to determine where the rain "pockets" are in the cloud, their actual extent, how they change with time, and their rainwater content. Further, the radar picture may be used to guide the aircraft into regions of particular interest so that the radar information may be supplemented by visual observation and direct physical measurements.

By means of this equipment conclusive evidence of rain formation both by the Bergeron process and by direct coalescence has been obtained.

(*b*) *Ground Radar Observations.*—While the use of an aircraft allows access to cloud areas within a range of 200 miles or more from base, there are many observations for which radar located at a fixed point on the ground is specially suited. Such an installation, fitted with an aerial system which scans from horizon to horizon through the zenith, provides a vertical cross-section through cloud areas in the vicinity. Since it can be operated continuously on suitable days it is particularly valuable for obtaining data on the relative frequency of occurrence of different rain conditions; and it is equally useful as an airborne installation for studying special phenomena which happen to occur above the station. Observations with this radar, unlike that in an aircraft, can readily be supplemented by measurements of the rainfall intensity and the size of raindrops actually reaching the ground.

(*c*) *Raindrop Sonde.*—The measurement of raindrop diameters from a fast-moving aircraft is difficult and equipment has therefore been developed which can be taken aloft by a balloon. This consists essentially of a microphone and a transmitter. The momentum of the raindrops as they strike the microphone is used to modulate the radio wave. It is thus possible to obtain on the ground a continuous record from which raindrop sizes can be determined as the microphone, carried by the balloon, ascends through the rain area. From the record the total rainwater content in a cloud can also be determined. The results obtained show that the rainwater content in a cloud generally increases downwards and that raindrops grow in size as they fall through the cloud.

(*d*) *Theoretical Aspects.*—It is now a well-established fact that rain can fall from clouds which are warmer than freezing and in which the ice-crystal mechanism postulated by Bergeron cannot be responsible for the rain.

Theoretical aspects of the possible growth of cloud droplets by processes involving both condensation and collision have been compared with the measurements made with the equipment described above. A theory, based on certain simplifying assumptions, has been advanced to account for the production of large drops by a combination of these processes, and the theory is being extended to cover the more complex conditions believed to exist in actual clouds.

(*e*) *Laboratory Experiments.*—Radio waves are scattered to a different extent by raindrops, ice crystals, and snow flakes. The interpretation of the radar pictures described above is, therefore, dependent on a knowledge of the laws of scattering by these particles. Laboratory measurements have been initiated to check these laws and, in particular, to obtain information on the change in reflectivity occurring when water droplets become frozen in various forms, for example as ice pellets, ice needles, or snow flakes.

## 8. ARTIFICIAL RAIN-MAKING.

In parallel with the work described above, experiments have been continued on the effects produced by treating natural clouds in several ways.

(*a*) *Dry Ice.*—In the "dry ice" process rain is induced by causing large numbers of ice crystals to form in the tops of clouds consisting of supercooled water droplets. The ice nuclei grow rapidly at the expense of the water drops, fall to the freezing level where they melt, and descend as rain.

Owing to the abnormally wet season experienced in the Sydney area, conditions for artificial rain-making by means of dry ice occurred much more rarely than in the previous year—for example, in only five out of 35 flights was suitable cloud found which was not already raining (compared with a ratio of 1 : 2 for the year 1948). The results of these relatively few new experiments, however, confirmed those previously obtained; it is concluded that the method has a high probability of success when applied to suitable clouds whose tops are at least 7° C. below freezing.

(*b*) *Silver Iodide.*—It is believed that finely divided particles of silver iodide behave in a manner analogous to that of ice crystals in inducing rain to fall. Spectacular results have been claimed for this process by Langmuir and others in the United States.

Although a few initial experiments on methods of dispersing silver iodide have been carried out, weather conditions in the vicinity of Sydney have been generally unfavorable and no report on the efficiency of silver iodide as a seeding medium can yet be given.

(*c*) *Water Spray Methods.*—Practical and theoretical investigations of non-freezing rain suggest that the introduction of water drops at the appropriate level into a suitable cloud should be effective in stimulating coalescence and the consequent rapid growth of droplets. Preliminary tests of this method have proved promising, and further experiments to establish the physics of the mechanism are in progress.

### 9. PRECIPITATION.

Last year's Report referred to measurements, made by the Division of Physics, of the number and types of ice crystals produced by solid carbon dioxide; these have revealed a marked dependence on temperature. At —4° C. about 5 by $10^{11}$ crystals are produced per gram of carbon dioxide evaporated, but at —20° C. the number is about 100 times as great. These results may be of practical importance in the use of carbon dioxide for the artificial production of rain. Similar investigations on the use of silver iodide for artificially stimulating ice crystal formation in a supercooled fog have shown that the number of crystals increases very rapidly between —7° C. and —12° C. This work is still proceeding. The techniques for studying the crystals produced have been improved, and are being applied in several phases of this work.

The capture of finer droplets by a falling droplet may be an important phenomenon in rain formation. An attempt is being made to measure the capture cross-section directly by determining the amount of mist collected by falling drops, using a mist containing a tracer material. As the presence of a chemical tracer material may modify the surface properties of the droplets, experiments have been made to estimate the magnitude of any error arising from this cause. An alternative approach to the problem of capture is also being made by measuring the growth of individual droplets suspended in a rising stream of mist.

It is well known that water in bulk does not readily supercool below about —10° C., whereas small droplets do not spontaneously freeze until temperatures of about —35° C. are reached. This suggests that the temperature at which drops freeze is a function of their size, and possibly of the time for which they are exposed to a given temperature. Reports by other workers are conflicting on this point, and because of its importance in the possible mechanisms of rain and hail formation, experiments are being conducted. The problem has also been examined theoretically.

### 10. CLOUD PHYSICS.

(*a*) *Vertical Air Velocity.*—Very few quantitative observations of the vertical air velocity in clouds exist, although a knowledge of it is fundamental to cloud study. A method which shows promise of giving information on the flow pattern in convective cells within clouds is being investigated by the Division of Radiophysics. It consists of sowing a horizontal line of very light reflecting material (that used during the war was known as "window") across the top of a cloud from an aircraft fitted with radar. The pattern taken up by this line of "window" as it falls is observed by means of the radar. Its rate of fall and hence the vertical air velocity in various parts of the cloud thus can readily be determined.

(*b*) *Cloud Water Content.*—As with vertical air velocity, few reliable measurements of the water content in typical clouds appear to have been made. Measurement from an aircraft is not easy, but an instrument which seems suitable for the purpose has been developed. In this experiment absorbent paper is exposed as the aircraft flies through the cloud. The cloud droplets impinge on the paper, producing a change in its resistivity, and measurements of this change of resistance allow the water content to be calculated.

(*c*) *Cloud Temperature.*—A knowledge of the temperature inside clouds is equally fundamental to an understanding of their properties. It is seldom, if ever, measured in an aircraft because of the difficulties arising when an aircraft thermometer becomes wet. The possibility of obtaining cloud temperatures by measuring the velocity of sound within the cloud is being investigated. It is thought that sound velocities will not be affected appreciably by the presence of water drops or ice particles.

(*d*) *Cloud Drop Spectra.*—Little basic information is available on the size of droplets to be expected in typical clouds, on their range of diameters (that is, on the "spectrum" of the drop sizes), and on how these diameters vary at different levels within a cloud or at any one level with time. These measurements are difficult and the most promising method appears to be one in which actual samples of the cloud are examined. A sampler of this type has been constructed for use in an aircraft and a number of measurements made. The cloud droplets are allowed to impinge on a cylinder coated with magnesium oxide, where each drop produces a hole of characteristic size in the film.

### 11. UPPER AIR INVESTIGATIONS.

(*a*) *Wind Finding.*—A knowledge of winds at heights above 30,000 feet is of increasing interest to civil and military aviation. A series of measurements of the speed and direction of winds at high altitudes has been obtained by using a high-powered radar set to track special reflecting balloons which are released from the ground. A novel feature of these experiments is that the balloons themselves are made to reflect the radar waves by coating their surfaces with a very thin layer of silver. The measurements have established that conditions over Sydney are apparently similar to those in corresponding latitudes in the northern hemisphere; that is, there is a region of strong westerly winds with a maximum at a height of 40,000 feet and these winds decrease to low velocities at greater heights, blowing either from the east or from the west according to the season. Further measurements over a longer period will be required, however, to establish more definitely the upper-air wind pattern in the vicinity of Sydney, and a radar set specially adapted for this work is in course of construction.

(*b*) *Homing Glider.*—Many useful measurements can be made from a vehicle carrying a variety of recording instruments, which can be despatched to great heights and safely recovered on its return to the ground. A homing glider is being developed for this purpose and has reached an advanced stage of construction. It has a total weight of about 10 lb., carries a radio receiver which, in conjunction with a ground transmitter, provides the necessary control signals to steer it back to the ground station, and is ntended to be carried aloft and released at a predetermined height by means of a balloon. It is likely to ave great advantages over powered flying models n that it has a high potential rate of ascent of 1,000 eet per minute, together with a high ceiling.

### 12. Expectation of Monthly Rainfall in South Australia.

The Section of Mathematical Statistics has broadened he scope of its investigation on expectation of monthly ainfall, mentioned in last year's Report (page 104). Using J. A. Prescott's formula, the amounts of rainfall necessary to balance average potential evapo-transpiration have been computed for all rainfall stations in the agricultural areas of South Australia, and work is now in progress to determine the probabilities that rain falling in runs of successive months will fail to reach the requisite amounts.

## XXVIII. EXTRATERRESTRIAL PHYSICS.

### 1. General.

The application of radio methods to the study of the universe around us—the birth of "radio astronomy"—marked a new era in the science of astronomy. Since the time of their formation the Sun and the stars have been steadily radiating away their energy, but until quite recently we have been conscious only of the part of this energy which reaches us in the form of light and heat. The great advances which have taken place in radio within the last decade have now made it possible to receive also the radio waves given out by the heavenly bodies. The use of radio methods has produced something of a revolution in astronomy, for two reasons. Firstly, they provide a new way of studying bodies which, by the older methods of astronomy, we already knew to exist. Secondly, they allow us to detect objects in the heavens of which we would otherwise be unaware, either because they do not give out enough light or heat to be detected by optical means, or because their light is partly or wholly obscured by dark patches in the sky, patches which are transparent to radio waves but impenetrable to the shorter-wavelength rays of light.

Of all the heavenly bodies the Sun is easily the most important to us, and a thorough understanding of the many complex processes which go on in its atmosphere is not only of scientific but of practical interest. The Division of Radiophysics has accordingly continued its investigations of solar noise. Further observations have also been made on cosmic noise (the radio waves which reach us from other portions of the galaxy) and, in particular, on those unique discoveries of radio astronomy, the radio stars. These are stars which can easily be detected by radio, though by optical means they are unimportant or even invisible. They must, therefore, emit radio energy on a vastly greater scale than they do light waves.

The work of the Division of Radiophysics in radio astronomy is described in Sections 2 and 5 below. This work is closely related to investigations being made by the Radio Research Board and the Division of Physics, which are outlined in Sections 3 and 4 respectively.

### 2. Solar Radiation—Work in Division of Radiophysics.

The intensity of the radio waves from the Sun has been observed systematically throughout most of the year on a number of wavelengths, namely 3, 10, 25, 50, 300 and 500 centimetres. During the partial solar eclipse of October, 1949, these observations were extended to include simultaneous observations on 25 centimetres at two sites, one in Victoria and one in Tasmania. During the previous year the Division had successfully developed the technique of using spaced receivers during an eclipse to determine the position of highly emitting areas on the Sun. The results this year may be less interesting from this point of view (the Sun was rather free from such areas on the day of the eclipse), but, on the other hand, more accurate measurements of the distribution of radio brightness across the quiet Sun were obtained.

In addition, several more elaborate series of observations were carried out: one of the radio spectrum of "bursts" of solar noise between 2.2 and 4.4 metres; and another of the location of the highly emitting areas on the Sun's disk, and the polarization of the waves of solar noise at a wavelength of 3 metres.

As a result of these observations and of theoretical studies based on them, it is now possible to recognize a "base level" of radiation over the wavelength range from 1 centimetre to 4 metres. This radiation is due to thermal emission from the hot gases of the outer solar atmosphere. Theoretical studies have enabled the radio results to be used to estimate the normal temperature and pressure of these gases at various heights above the visible surface of the Sun.

Increases above this base level of intensity frequently occur as a result of various disturbances, and different components can be recognized. The first is a slowly varying component which is evident at wavelengths from 3 to 50 centimetres. Investigations are in progress to see whether it is due to thermal emission from exceptionally hot regions in the solar atmosphere. The temperature scale is quite outside ordinary experience. That of the "quiet" solar atmosphere ranges from 6,000° C. (the level seen by the naked eye) to one million degrees in the corona. The "hot spots", if they exist, must be at temperatures more like ten million degrees, but they are not visible optically because the rarefied gases in which they lie are transparent.

The second component is noticed at metre-wavelengths during so-called "noise-storms". The intensity rises and often fluctuates rapidly for periods of hours or days, and the radiation is known to be associated with certain sunspots. The latest observations show that with the rotation of the Sun the apparent source travels across the Sun faster than the associated sunspot, indicating that the source is very high up in the solar atmosphere.

The third and fourth components, "outbursts" and "isolated bursts" respectively, are sporadic and short-lived phenomena. At the time of great "flares" on the Sun it is believed that streams of gas are ejected which, a day or so later, reach the Earth and cause magnetic storms and auroras. It has not been possible to see these streams of gas at the Sun. At the time of the flare, however, radio waves, called "outbursts", are emitted, which may be associated with these "eruptions" in the solar atmosphere. The onset of the disturbance occurs first on short wavelengths and is progressively delayed as the wavelength increases. This would correspond to the progress of the ejected gas outwards in the solar atmosphere with a velocity of the order of 1,000 km./s., at which it is known to travel between the Sun and the Earth. Simultaneously the apparent place of origin moves from the region of the flare outwards in the expected manner. If this association proves correct, solar noise studies will provide many more details of this most spectacular but elusive type of solar disturbance.

The fourth component, the "isolated bursts", are not yet associated with any optical phenomena and at present are the sole evidence for a remarkable type of disturbance of a few seconds' duration which certainly occurs in the solar atmosphere.

### 3. SOLAR RADIATION—WORK OF RADIO RESEARCH BOARD.

The Radio Research Board is studying the effects of bursts of radiation from the Sun in producing variations in the ionosphere and in the magnetic field of the Earth (*see* Chapter XXVI., Section 12).

### 4. SOLAR RADIATION—WORK OF THE DIVISION OF PHYSICS.

Last year's Annual Report described theoretical investigations on solar flares, the hydrogen spectrum of the Sun, and the temperature distribution of the Sun's atmosphere. In continuation of these studies, the Division of Physics has begun construction of a spectroheliograph to take cinematograph records of solar phenomena. This instrument will be used in two projects; firstly, to carry out studies of active centres on the Sun, including solar flares and prominences; and secondly, to survey the Sun for correlations of phenomena which can be recorded optically with the emission by the Sun of radio-frequency radiation. The latter project will be carried out in co-operation with the Division of Radiophysics.

The instrument will include a birefringent filter of the type first developed by Lyot in France. The design and construction of the spectroheliograph, except the birefringent filter which is being obtained from abroad, are being undertaken in the Laboratory. Some experimental birefringent filters, however, have been made in the optical workshop, and experience in operating such filters has been obtained.

The complex solar phenomena which modern equipment reveals can be elucidated only by thorough theoretical analysis which takes into account all the known physical processes that may contribute to the observational result. During the past year theoretical studies on the emission of radiation from hot atmospheres such as the solar chromosphere—one aspect of the general problem—have been continued. This investigation required improved data on atomic collision probabilities, which have been obtained.

### 5. GALACTIC NOISE.

Observations of galactic noise over the past year fall into two broad divisions: those aimed at finding its general distribution, both in position and in wavelength, and those concerning the point sources, the "radio stars". A careful and comprehensive survey of the distribution of intensity over the sky on a wavelength of 3 metres was completed. Spot measurements have also been made of the radiation from the most intensive part of the Milky Way on 10 and 25 cm., and a preliminary survey has been made on 15 metres of the distribution over a part of the sky.

(*a*) *General Distribution.*—The mechanism by which galactic noise originates is still not established, and measurements over the above wide range of wavelengths were used in order to show that one of the theories, viz., that it originated in thermal radiation from the vast clouds of very rarefied ionized gas which exist in space between the stars, was inadequate to explain the facts. The evidence suggests that part of the radiation arises from this interstellar gas, but that some other mechanism must also exist.

It has also been observed that the distribution of intensity over the sky conforms closely with what is known of the distribution of matter within the galaxy. It is, therefore, a reasonable assumption that, whatever the mechanism, the distribution of sources of galactic noise is broadly consistent with that of matter in the galaxy. However, since radio waves, unlike light waves, are not absorbed to any great extent in the clouds of dust which restrict our optical view of parts of the galaxy, the radio distribution shows much more detail. The outstanding discovery is that, in addition to the strong concentration towards the centre of the galaxy, there is an important maximum 90° removed from this. The natural explanation is that this is due to a spiral arm and that the galaxy in which we are situated is a spiral, like, for example, the often-photographed "Andromeda Nebula". This involves a revision of the present ideas of astronomers on the sense of rotation of galaxies. Our galaxy rotates, not like a catherine wheel with the arms trailing, but in the contrary sense, with the arms pointing forward.

(*b*) *Radio Stars.*—Observations on radio stars have continued and include—

(i) The discovery of about twenty new ones.
(ii) Studies of the fluctuations in intensity of individual radio stars.
(iii) Measurements of the energy spectra of certain of them.
(iv) Development of equipment for more precise position-finding.

Radio stars present two puzzles. Firstly, what are they? And secondly, why do they fluctuate in intensity with a period of seconds or minutes?

No firm answer can yet be given to the first question, but observational data are accumulating. An interesting observation is that the distribution of the radio energy between wavelengths of about 1½ and 5 metres differs for different radio stars, which suggests that there are probably at least two types. One, strangely enough, has the spectrum of thermal emission from a hot, very rarefied gas at a temperature of a few million degrees. The others are incompatible with this. The most important next step will be the precise location of a considerable number in order to identify them, if possible, with visible objects.

The question of the fluctuations is approaching solution. The fluctuations are not the same at points on the Earth a few tens of miles apart, which suggests that they are of relatively local origin. The correlation between fluctuations and irregularities in the ionosphere is being examined, and it has been shown that the fluctuations from a single source show an annual variation. It is probable that the fluctuations will prove to be due to scattering effects from irregularities in the ionosphere, analogous to the visible twinkling of stars which is due to refraction by irregularities in the lower atmosphere.

## XXIX. ATOMIC PHYSICS.

### 1. GENERAL.

The Organization is co-operating with the Physics Department of the University of Melbourne in a programme of research on nuclear physics and cosmic rays under the direction of Professor L. H. Martin. The nuclear physics investigations make use of high-energy particles produced artificially by high-voltage electrostatic generators, whilst in the cosmic ray studies the disintegration produced in the upper atmosphere by high-speed particles reaching the earth from outer space is analysed. The ultimate aim of both researches, however, is to further understanding of the constitution of the atomic nucleus and of the forces which hold it together. They are described in Sections 2 and 3 below.

Co-operative investigations on cosmic rays are also being undertaken at the University of Tasmania under the direction of Professor A. L. McAulay (*see* Section 4).

By arrangement with the Commonwealth Department of Health, the Tracer Elements Unit has continued to operate in association with the Commonwealth X-ray and Radium Laboratory. This Unit provides a service for the procurement, processing, and application of radio-isotopes in medicine and research work. Its activities are described in Section 5 below.

### 2. NUCLEAR PHYSICS.

(*a*) *Million-volt Electrostatic Generator.*—The performance of the electrostatic generator has been very satisfactory, although some trouble was caused by deterioration in the insulating properties of the column supporting the high-potential electrode. Installation of a double-belt charging system, replacing the former single-belt system, has increased the charging current to some 400 $\mu$A, a considerable improvement on the 240-$\mu$A charging current obtained with a single belt. In addition to this major advance, several minor changes have improved performance and reliability.

Investigations on the angular distribution of the $\alpha$-particles and protons from the $Li^6$ (d, $\alpha$) $He^4$ and $Li^6$ (d, p) Li reactions are being made with the aid of the million-volt generator. This research follows a completed investigation on the angular distribution of the $\alpha$-particles from the $Li^7$ (p, $\alpha$) $He^4$ reaction. The method used is the same; nuclear emulsion plates are exposed to the product particles from a target of lithium, placed in the centre of a camera which permits registration in the emulsion of particle tracks in the angular range 13° to 90° and 167° to 90° to the incident deuteron beam. Considerable preliminary research has been carried out to determine the best method of differentiating the $\alpha$-particle and proton tracks produced in the emulsion as a result of $Li^6$ (d, $\alpha$) and $Li^6$ (d, p) reactions. The determination of the angular distribution of the $\alpha$-particles for incident deuteron energies between 200 keV and 1 MeV is almost complete. The analysis of the proton results is now in hand.

Preliminary work on the development of a scintillation counter for counting $\alpha$-particles and protons has been finished. The counter consists of a zinc sulphide screen used in conjunction with a photomultiplier tube, the electrical impulses from the photomultiplier being fed to a discriminator and scaling unit. The scintillation counter has been fitted into equipment designed for measurement of angular distribution of the product particles of nuclear reactions. The $Li^7$ (p, $\alpha$) $He^4$ reaction will be first studied using this technique.

A 12-stage electron multiplier tube for the detection of charged particles of very low energy has been constructed. This will be used to investigate the angular and energy distributions of the protons scattered by lithium, and of the low-energy $\alpha$-particles produced in the $Li^7$ (p, $\alpha$) reaction.

The determination of a range-energy curve for protons of energy less than 5 MeV in Ilford nuclear research emulsions is nearing completion. Proton tracks obtained in the $Li^6$ (d, p) and $C^{12}$ (d, p) reactions have been used in this investigation. The estimated accuracy of the results so far obtained is better than 1 per cent., which compares favorably with the accuracy obtained by other workers.

(*b*) *600-kilovolt Electrostatic Generator.*—An electrostatic generator is being constructed to give a beam current of the order of 100 $\mu$A. at a maximum potential of some 600 kV. It is intended that the machine will be used to provide high-intensity sources of neutrons and gamma rays. The high-voltage terminal is to be supported on four columns of porcelain insulators, and corona rings will completely encircle the four columns, enclosing also the accelerating tube and the four charging belts. The assembly of the high-voltage portion of the equipment is now almost complete.

(*c*) *Electron Synchrotron — Photo-disintegration Investigations.*—The electron synchrotron is operating satisfactorily as a 13-MeV X-ray generator, giving an ionization intensity of 0.4 roentgen/minute at a distance of one metre.

The photo-disintegration of the deuterium nucleus by high-energy quanta is to be studied, using an expansion chamber synchronized to the X-ray pulse. The splitting of the deuterium nucleus is considered theoretically as resulting from interaction with either the electric or the magnetic field of the incident quantum. Experimental data on the angular distribution of the recoil protons in the cloud chamber will give information upon the actual nature of this process for quanta of all energies, from the threshold value 2.2 MeV up to about 10 MeV. Most of the experimental evidence at present available has been obtained with nuclear emulsion plates. By using an expansion chamber, information will be obtained at lower energies near the threshold energy, and in addition a check on nuclear emulsion plate work at higher energies will be possible.

(*d*) *Mass Spectrometer—Isotype Separation.*—The mass spectrometer has been used throughout the year to provide the $Li^6$ targets used in the angular distribution experiments described above. The instrument is now being modified to separate isotopes of magnesium.

(*e*) *$\beta$-ray Spectrometer—Positron and Electron Scattering.*—An investigation of the differences in the behaviour of positrons and electrons when they are scattered by a thin gold foil is being carried out. To obtain positrons of a single energy, a magnetic-lens type $\beta$-ray spectrometer has been constructed and has reached the calibration stage. The special set of Geiger counters required to record the scattering intensities at varying angles is in process of construction.

(*f*) *Electronically-controlled Expansion Chamber.*—The expansion chamber is complete and the control circuits are being developed. This expansion chamber is designed for operation with the 600-kV electrostatic generator.

### 3. COSMIC RAY STUDIES.

(*a*) *Study of Cosmic Ray Bursts in Ionization Chambers.*—The transition effect in lead for cosmic ray bursts in an ionization chamber has been studied and the various factors that contribute to this effect determined. It has been possible to separate out contributions from the following agencies: nuclear disintegrations, extensive showers, narrow showers, single high-energy photons and electrons, and nuclear events producing showers. Simultaneously the decohesive curves for narrow and extensive showers were determined by coincidence techniques, together with the distribution functions for such showers.

(*b*) *Cosmic-ray Spectrometer.*—The equipment constructed for the measurement of the cosmic ray momentum spectrum has been in operation since June, 1949. During this period some 7,000 meson tracks have been analysed with the instrument operating vertically. The preliminary results of this experiment have been published. Additional results now confirm that the momentum spectrum above $10^{10}$ eV/c falls off much more rapidly than was indicated by previous experiments. Also the distribution has a peak at approximately 5 x $10^8$ eV/c, a value which agrees more closely with absorption measurements. The measurement has been repeated at zenith angles of 30° and 60° and the results are being analysed.

A proportional counter has been constructed to operate in conjunction with the spectrometer. The preliminary tests have been satisfactory and it is proposed to investigate the specific ionization-momentum relationship.

(*c*) *Meson Decay.*—Apparatus for measuring the life times of $\mu$ mesons is now in operation, positive mesons being concentrated on an aluminium absorber. Preliminary results show that a higher rate of collecting data must be attained if the accuracy of previous workers' results is to be improved and the measurements to be extended to absorbers of high atomic number in which the mean life of negative mesons is short and the frequency of observed meson decay low. To achieve this, a larger magnet and counting arrangement for separating positive and negative mesons is being designed.

The timing circuits are performing satisfactorily. The lifetimes are recorded photographically from a cathode-ray tube using a spiral time base that makes one revolution per microsecond. The separation between two radial blips gives the lifetime. These blips, which rise in $10^{8}$ second, are produced by a radial deflection circuit which is, as far as is known, unique. The signal delay line, which allows the time base to be started by the coincidence-anticoincidence pulse before the signals arrive at the radial deflection circuit, is of the continuously wound equalized type.

Progress has been made with the design of an experiment to determine the energy spectrum of the electrons resulting from $\mu$ meson decay.

(*d*) *Absorption Measurements of Cosmic Rays in Water.*—Geiger counter equipment for the precision measurement of the integral and differential range spectra in water, up to a depth of 90 feet, has been designed and is nearing completion. Measurements of the absorption in lead have given results which differ by more than the experimental errors. The present experiment is intended to determine the cause of these discrepancies, to extend the range to greater amounts of absorber, and to allow a comparison with the results obtained with the cosmic ray spectrometer.

### 4. COSMIC RAY STUDIES—HOBART.

The measurements of the high latitude east-west asymmetry at Hobart mentioned in the last Annual Report were continued. The aim of these experiments is to obtain data to test Johnson's theory of the asymmetry at high latitudes. Larger apparatus is to be constructed, to permit results to be obtained more rapidly.

### 5. TRACER ELEMENT INVESTIGATIONS.

In common with other countries, Australia is making increasing use of radioactive tracer elements in research, and this is progressively widening the programme of the Unit.

(*a*) *Procurement and Distribution of Isotopes.*—Supplies of pile-produced radio-isotopes are now obtained regularly from the Atomic Energy Research Establishment, Harwell, with the exception of $S^{35}$ and $C^{14}$, which are still supplied only by the United States Atomic Energy Commission. Several shipments of cyclotron-produced materials have been provided free of charge by the Department of Terrestrial Magnetism of the Carnegie Institution, Washington.

The 63 shipments for the year consisted of eleven different isotopes. These were supplied to the Commonwealth Department of Health for medical use, and for research purposes to five Divisions of the C.S.I.R.O., the Chemistry Departments of the Universities of Adelaide, Melbourne, and Sydney, the Physics Department of the University of Melbourne, the Victorian Department of Agriculture, the Sydney Dental Hospital, and the New South Wales Bread Research Institute.

(*b*) *Radio-iodine in the Thyroid.*—Work has continued, in collaboration with Dr. R. Kaye Scott, at the Royal Melbourne Hospital, on diagnostic and therapeutic studies of cases of hyperthyroidism and of thyroid carcinoma, using radioactive iodine. Fifty cases were so investigated, including some for other hospitals.

When radio-iodine is taken up in the thyroid gland it is distributed very unevenly within the tissue, resulting in a widely varying dosage of radiation from the beta-rays, which have only a very short range (about 2 mm.) in tissue. Practical and theoretical investigations of this problem of non-uniform radiation dosage have shown the need for further work, and arrangements are in train for this to be undertaken jointly with the Biochemistry Department of the University of Melbourne.

(*c*) *Labelled Compounds.*—In tracer work it is often necessary to work with a particular chemical compound which incorporates a suitable isotopic atom as a "label". Such labelled materials are often not available from abroad, or their cost in dollars is very high, and consequently there has been a considerable increase in the local demand for isotopically-tagged chemical compounds. Materials already made include: deutero-methyl bromide for work on chemical bond strengths in the Chemistry Department of the University of Melbourne; $S^{35}$-labelled methionine for studies with clothes moths in the Division of Entomology, and for other work in the Wool Textile Research Laboratories and the Division of Industrial Chemistry; and $I^{131}$-labelled plant hormones for the Division of Plant Industry. Further materials are now being prepared, chiefly $C^{14}$-labelled organic compounds for use in the study of red blood cells at the Institute of Medical Research, Royal North Shore Hospital, Sydney, and for other work at the McMaster Animal Health Laboratory. Temporary accommodation is being provided for one of the research staff of the Chemistry Department of the University of Adelaide, to assist with the synthesis of three labelled ketones, which will be used to investigate the mechanism of the Ponndorf reaction.

(*d*) *Pilot Experiments.*—Help with pilot experiments, temporary accommodation, and counting equipment has been given to several C.S.I.R.O. Divisions and various outside organizations.

The experiments of the Victorian Department of Agriculture with long-lived radio-manganese to study manganese-molybdenum antagonism in plants are continuing with new material obtained from the United States Department of Terrestrial Magnetism, and with material salvaged from the residues of previous experiments.

Steel balls made radio-active with $P^{32}$ have been prepared for the Division of Building Research for use in a gas elutriation apparatus mentioned elsewhere in this Report.

(*e*) *Radio-active Assay.*—Because of the growing interest in tracer methods, there has been a strong demand for radio-active assay equipment. Sixteen lead castles have been made for various users, and a further twelve are under construction.

Valuable help has been given by the Central Experimental Workshops of the Organization in developing several devices to facilitate the handling of radio-active material and the preparation of samples in a reproducible form suitable for assay. For example, a micro-pipette control device has been constructed which enables precise volumes of material to be deposited on assay pans without the need for an expensive air-damped chemical balance.

(*f*) *Information.*—A further sixteen supplementary lists of references, covering applications of tracer elements to particular fields of research, have been issued this year. In addition, specialized lists have been prepared, as requested, for individual workers.

Advice on technique, protective methods, and necessary apparatus has been given to University Departments and C.S.I.R.O. Divisions setting up laboratories for research requiring tracer materials. Information has also been given to several commercial firms on the suitability of certain radio-active materials for industrial purposes.

# XXX. MATHEMATICS.

## 1. General.

The Section of Mathematical Statistics, which is located in Adelaide, was set up by the Organization to provide skilled mathematical assistance in the planning of experiments, more especially in the biological sciences, and in the interpretation of experimental data. Its work is described in Section 2 below.

The design and construction of mathematical instruments, and the development of mechanical and electronic methods of computation, are the concern of the Section of Mathematical Instruments (*see* Section 3). During the last year similar work was undertaken by the Divisions of Radiophysics (Section 4 (*a*)–(*d*)) and Electrotechnology (Section 4 (*e*)) and by the Section of Meteorological Physics (Section 4 (*f*), for the purposes of their own investigations.

## 2. Section of Mathematical Statistics.

The Section's work has, as before, been connected primarily with the experimental programmes of the individual units of the Organization and of other bodies, involving the designing of trials and subsequent analysis of the results. With the general expansion of these research projects, and the growing awareness among outside bodies of the need for statistical techniques in the planning and interpretation of their experiments, there is an increasing demand for assistance of this kind.

With head-quarters in Adelaide, and officers located also in Canberra, Sydney, and Melbourne, the Section has been able to assist in the Organization's investigations at each centre and maintain close contact during progress of the experiments—some of them of a large-scale nature—discussed elsewhere in this Report.

The Section's own research programme has progressed, and certain results have been published during the year. Two major pieces of work relating to South Australia—one on the influence of rainfall on wheat yield, the second on the expectation of monthly rainfall—are described in Chapter III., Section 23, and Chapter XXVII., Section 12. In addition, the following investigations have been completed.

(*a*) *Sampling Theory of Multivariate Normal Distributions.*—The theory of differential forms and integral invariants has been employed to establish a far-reaching result in the theory of sampling from normal multivariate distributions. In applying this result, new, concise, and much clearer solutions have been obtained for a number of problems in statistical theory, and the investigations are being continued in view of their important and wide practical applications.

(*b*) *Experimental Designs.*—A frequently occurring and important class of experiment is one in which different treatments are applied in succession to the same unit of experimental material, and under these conditions it is necessary to consider the residual effects of preceding treatments on the latest treatment. For example, in crop rotation trials where the object is to determine the succession of treatments over a number of years which will give the best results for the series as a whole, the estimation of the effects of previous treatments is of direct interest whether the criterion is yield, market value, or the maintenance of soil fertility. In other situations, such estimations may be of indirect concern only. Thus in feeding experiments with animals, a series of treatments (rations) may be fed to a group of animals, with the primary object of determining which particular ration gives the best results according to some predetermined criterion. The effect of previous treatment would be of indirect interest, and would be estimated only to provide a correction in estimating the effect of the treatment which followed.

A series of experimental designs, balanced for the residual effects of treatments, has been developed to facilitate interpretation of the results of such experiments.

(*c*) *Increased Precision of Growth Indices.*—In plant physiological studies, growth indices such as the relative growth rate and the net assimilation rate have been employed in the interpretation of experimental data, but their value for this purpose has hitherto been limited owing to the large errors involved. Following a theoretical investigation of this problem, a statistical procedure has now been developed whereby the precision of estimation of growth increments and the various growth indices is greatly increased, especially under conditions of high variability, thus enhancing considerably the value of these indices in growth studies.

## 3. Section of Mathematical Instruments.

The Section of Mathematical Instruments has been operating now for a full year in the Department of Electrical Engineering of the University of Sydney. Its close proximity to the Vacuum Laboratory has permitted interchange of ideas on the development of tubes for special computing applications. The Section has also provided facilities for honours students in the Faculty of Electrical Engineering to work on special projects associated with its programme. The principal work of the Section is set out in the following paragraphs.

(*a*) *Differential Analyser.*—Although the manufacture of the integrators is not yet completed, four units have been delivered and the remaining six are expected soon. The other units, including the control unit, have been constructed and the machine is ready for limited operation. Its capacity will be extended as further integrators arrive. During the year the machine has been used for a number of problems requiring laborious integrations in auto-correlation and spectral density of atmospheric temperature fluctuations.

(*b*) *Digital Computing Machines.*—Work has been confined to study of the basic units of high-speed digital machines. In particular, the Section has been concerned with developing the electrostatic storage unit and a magnetic drum store.

In connexion with the magnetic drum the problem of high-speed switching and gating of large currents arose. A suitable switch was developed and tested, using saturable reactors. Ratios of gated to suppressed outputs as high as 6,000 were obtained.

A shift register has been constructed, to "staticize" and "dynamicize" binary coded data for feeding into and out of the memory device. This unit is also to be used as an accumulator in developing an arithmetical unit for the machine.

(*c*) *Other Activities.*—The Section maintains a strong interest in servo-mechanism problems. During the year an experimental model of an automatic curve follower for use with the differential analyser was developed by an honours student in the Faculty of Electrical Engineering.

## 4. Mechanical and Electrical Computation Methods.

During the past year the major effort of the Mathematical Physics Group of the Division of Radiophysics has been devoted to studying numerical processes, to applying them on a large scale to various problems arising within the Division and in other branches of the Organization, and especially to assembling and testing various units of the electronic computer which has been designed and is being constructed in the Division. The Division of Electrotechnology has developed an electronic decade counter tube, and a machine that gives the product of two continuous time series has been built by the Section of Meteorological Physics.

(*a*) *Electronic Computer.*—Good progress has been made with this machine during the year. Most of the essential elements were completed and assembled. The successful operation of such a machine depends upon the adequacy of the instructions supplied to it and considerable attention has therefore been given to the design of programmes by which the machine will be put to use. The methods for controlling the computer and for performing certain types of computations have now been completely defined. Several programmed calculations of a simple nature but designed to involve the important functions provided in the machine have already been successfully completed, and the computer is now undergoing final modification prior to being put into regular operation.

Early in the year the Division of Radiophysics began work on developing an intermediate storage unit for use with this computer. This will make use of a rotating drum coated with suitable magnetic material. It should provide a simple but controllable memory unit in which sets of tables (for example, those of standard functions) may be permanently recorded. The machine may then readily refer to these as may be required during calculations.

(*b*) *Punched Card Equipment.*—Several additional units of the Hollerith range of punched-card equipment were obtained and placed in service. This computing system is made up of a number of standard Hollerith units which were originally designed for business accounting processes. Their mode of operation, however, renders them equally suitable for solving some of the detailed and time-consuming numerical problems which frequently arise in scientific work.

Methods of programming the Hollerith equipment for these purposes have been developed, and since October last the machines have been used extensively for large-scale computation, not only for the Division of Radiophysics but also for the Section of Meteorological Physics and the Division of Industrial Chemistry. The problems involved have included autocorrelation and cross-correlation of large masses of data, Fourier and generalized harmonic analyses, and the solution of linear equations of large order, of simultaneous equations, and those which arise in general statistical work.

(*c*) *Relay Multiplier.*—This machine has been designed to work in conjunction with punch-card equipment; it incorporates features which make it more suitable than the standard Hollerith decimal multiplier. It is being built within the Radiophysics Laboratory and is nearly completed.

(*d*) *Computing Methods.*—While the Hollerith equipment is being used extensively on problems of current interest, ways and means of tackling other classes of work are being devised and tested. For example, a method of solving partial differential equations is being developed and a useful convergent method which, with modification, may be used on an electronic computer has already been established.

(*e*) *Electronic Decade Counter Tube.*—Following the development by the Division of Electrotechnology of an experimental electron beam tube for counting in the scale of five, a tube of improved design for counting in the decimal system has now been produced. A number of these tubes may be operated in a chain to divide the incoming electrical signals by ten so that succeeding tubes register units, tens, hundreds, and so on. The stored count is indicated by electronic projections of images of the figures 0 to 9 centrally on the end of the tube. The tube, which has a diameter of 1.1 inch and a length of about 6 inches, requires a maximum of only 500 volts for its operation and at present for accurate counting has an upper frequency limit of 60 kc/s. The design is being improved to raise this frequency limit and to simplify the construction of the tube for commercial production. If a decade counter tube of this type were available in a single envelope, it would simplify the construction of electronic digital computers.

In developing this tube, it has been necessary to investigate the deflection of low-voltage electron beams and to determine the shapes of electrodes for producing the desired electron trajectories. As the usual method of making the required calculations is comparatively slow, the design and construction of an electronically operated electron path tracer has been undertaken. This will be used in conjunction with large-scale models in an electrolytic tank, and should speed up computation considerably.

(*f*) *Machine for Meteorological Calculations.*—A calculating machine has been built by the Section of Meteorological Physics to give the value of the product of two continuous time series. This covers a need which often arises in analysing data in connexion with the fundamental work of the Section. The machine follows the principle of the differential analyser, and can be used to generate mathematical functions and perform a variety of statistical operations in the analysis of elements whose fluctuations are continuously recorded.

## XXXI. INFORMATION AND LIBRARY SERVICES.

### 1. General.

It is obviously of great importance for the results accruing from the Organization's research programme to be made available to those who are interested in their application to the problems of industry.

Research results are published through a variety of scientific journals catering for the special needs of the various branches of scientific endeavour, including specialist journals published overseas. The Organization itself publishes, in collaboration with the Australian National Research Council, the *Australian Journal of Scientific Research*, which is issued in two series, Series A dealing with physical sciences and Series B with the biological sciences. It has also established three new journals: the *Australian Journal of Applied Science*, the *Australian Journal of Agricultural Research* (in collaboration with the Australian Institute of Agricultural Science and the Australian Veterinary Association), and the *Australian Journal of Marine and Freshwater Research*. Longer reports are published in the Organization's Bulletin series.

The Divisions and Sections maintain close contact with the various branches of industry interested in their particular research projects. In the case of agricultural research, direct contact with the man on the land is difficult but the extension officers of the various State Departments of Agriculture help to bridge this gap. An endeavour has been made to keep State officers advised of research progress, for example, through the medium of special schools dealing with particular subjects.

Various series of trade circulars and newsletters are issued to provide industry with technological information and articles of a similar nature are prepared for trade publications. The Organization also collaborates with other bodies in the preparation of special pamphlets dealing with its research results.

The information officers and technical secretaries attached to various Divisions and Sections give a great deal of help to industry by answering specific nquiries either from the accumulated experience of he scientific staffs of the laboratories or from the iterature. They are assisted in this work by the entral Information Service established at the Organization's Head Office (*see* Section 2 below).

To enable the scientific staff to keep up to date with overseas research, special library facilities have been built up, both at the Head Office and within the Divisions and Sections (*see* Section 3 below). The Information Service is able to give valuable assistance with this work, particularly through its Translation Section.

As far as possible, direct contact is maintained with workers in overseas laboratories. This is helped considerably by visits overseas by members of the scientific staff, although the number of officers who can be sent for this purpose is limited. The liaison offices in the United Kingdom and North America are able to assist in following up specific inquiries and in facilitating the visits of members of the research staff (*see* Section 4 below).

### 2. INFORMATION SERVICE.

The work of the Information Service has continued on the pattern outlined previously. The most important development during the year was the establishment of a new section, Abstracting and Documentation Section, which is concerned with abstracting, indexing, the writing of scientific articles, the compilation of scientific registers and directories, and the study of the methods used in documentation and of overseas developments promising improvement in the effective dissemination of scientific and technical information. This activity is deemed to be of lasting value to the whole body of scientific workers.

The Information Service is concerned with the implementation, in Australia, of the recommendations made by the Royal Society Scientific Information Conference in June-July, 1948. The Australian National Research Council has set up a "National Committee on Scientific Information" as the counterpart of the Royal Society Standing Committee on Information Services. This Committee is convened by the representative of the C.S.I.R.O. Information Service and includes representatives of the Australian National Research Council, the Library Association of Australia, and the Australian Association of Special Libraries and Information Services. By arrangement with U.N.E.S.C.O. it will also act as the Australian Regional Committee on science abstracting, the establishment of which was called for in the final recommendations of the U.N.E.S.C.O. Conference on Science Abstracting held in Paris last year. The Committee aims to keep in touch with developments affecting the dissemination of scientific information and will be available to assist and advise regarding this subject.

The Service has continued as an active member of the Industrial Information Advisory Committee. This Committee is now of four years' standing, and continues to serve as a useful clearing point for problems covering the supply of scientific and technical information to industry. Monthly meetings have continued and close collaboration of the three constituent bodies has been achieved.

(*a*) *Information Section.*—(i) *Inquiries.*—The volume of inquiry work has been maintained and the subject distribution generally ran parallel to that of previous years. There was a slight increase in the proportion of inquiries received from Government departments, particularly the Division of Industrial Development of the Ministry of National Development.

(ii) *Bibliographies and Summaries of Information.*—Twenty-one bibliographies and summaries of information were prepared in the course of dealing with inquiries, and selected lists published as before in appropriate technical and trade journals. At the request of the New South Wales Branch of the Library Association of Australia, a selected list of the Section's total production of bibliographies and summaries of information was compiled and this was published in "Special Libraries Leaflet No. 36—March, 1950".

(*b*) *Abstracting and Documentation Section.*—This Section has been in operation as such for only two months.

(i) *Australian Chemical Abstracts.*—The preparation of abstracts of chemical literature appearing in Australian periodicals has continued and the Technical Information Section of the Defence Research Laboratories has contributed abstracts of metallurgical papers. These abstracts have been collated and published as "Australian Chemical Abstracts", a supplement to the *Journal and Proceedings of the Royal Australian Chemical Institute.*

(ii) *Index to C.S.I.R.O. Publications.*—Work is well under way on the compilation of a comprehensive index of the publications of the Organization. This will include also research papers by C.S.I.R.O. staff which have appeared in external publications.

(iii) *Phytochemical Register of Australian Flora.*—Following the developments outlined in last year's Report, the Standing Committee has appointed representatives in each State and in the Australian Capital Territory. These representatives will be responsible for organizing voluntary assistance to carry out the specific portions of the survey allotted to the various regions. Stocks of standard forms and copies of a list of Australian genera of flowering plants and vascular cryptogams (compiled with the assistance of an officer of the Victorian National Herbarium) have been supplied to representatives, and work is proceeding. The Information Service will collate and file the results of the survey as they come to hand.

(iv) *Special Projects.*—Good progress has been made on Directories of Australian Scientific Societies and of Research Institutions respectively. The response to questionnaires has been encouraging and collation is now proceeding.

(*c*) *Sydney Office.*—During the year, 1,227 inquiries were received—an increase of about 8.4 per cent. on the previous year. About 811 inquiries were dealt with summarily by telephone. The remainder required more extensive action, and of these about 13.5 per cent. were referred to the Melbourne Office, and about 38 per cent. to other C.S.I.R.O. units, Defence Research Laboratories, or other authorities.

(*d*) *Translation Section.*—During the past year the increased demand for translation within the Organization has reduced almost to vanishing point the amount of translation which the Section has been able to carry out for other governmental and research bodies. Material assistance has, however, been given to these bodies by endeavouring to keep them informed (by means of the circulation of contents lists) of the nature and scope of material appearing in certain foreign-language journals.

The substitution of oral for written translation has been used as far as possible, and this has been assisted by the stationing of a full-time translator in Sydney to replace the part-time translator formerly there.

Further, a considerable amount of translation has been avoided by the use of the British D.S.I.R. translated contents lists of Russian periodicals. A parallel move to obviate duplication of work by setting up machinery to permit interchange of translations between countries of the British Commonwealth has been proceeding. B.C.S.O., London, is acting as the co-ordinating centre for this scheme. Copies of several important translations on soils have been sent to a number of local and overseas bodies likely to be interested.

The languages handled by the Translation Section are German, Dutch, Swedish, Norwegian, Danish, Latin, French, Italian, Spanish, Portuguese, Ancient Greek, Hebrew, Russian, Polish, Ukrainian, and Lettish.

Anticipating an increase in the demand for translation from Asiatic languages, the Section took steps to enlarge its scope by advertising its desire to contact those proficient in this group, but the response was disappointing.

Linguistic resources of C.S.I.R.O. officers have been tabulated from the replies to a circular sent out to the Divisions and Sections during the year. It turns out that the Organization includes officers familiar with Bulgarian, Turkish, Serbian, Czech, Hungarian, Rumanian, Lithuanian, Chinese, and Japanese. The panel of private translators adds to the above list Icelandic, Finnish, Indonesian, and High and Low Malay.

(e) *Ciné-photography Section.*—The interest of the Divisions and Sections in ciné films as a means of showing the results of certain research work is increasing. Films have been well received both in Australia and overseas, and copies have been sent to the Australian Scientific Liaison Offices in London and Washington. In addition some films have been donated or sent on exchange to Government research organizations overseas.

Two films on irrigation principles and practice designed for use by the Extension Service of the New South Wales Department of Agriculture were produced during the year.

The film library has grown somewhat, and now holds 45 films. Loans during the year represent about 150 screenings of overseas films and 100 screenings of C.S.I.R.O. productions. Additional screenings have also been arranged by other C.S.I.R.O. units. As scientific films often rely on animations and diagrams, the Section has acquired the necessary equipment and now designs and records most of the animated sequences for its own productions.

The following 16-mm. sound-on-film releases were made during the year:—

- "The Aims of Irrigation" (colour).
- "The Importance of Flow in Furrow Irrigation" (colour).
- "The Division of Radiophysics 1949" (black and white).
- "Purse Seining—A New Australian Fishery" (colour).
- "The Course Plotter" (black and white).
- "Northern Australia Regional Survey Part 2—The Barkly Area" (black and white).

The projected film, "C.S.I.R.O. Part 2—Secondary Industry and Physical Sciences" will not now be issued as such, but it is proposed to produce a series of Divisional films of which "The Division of Radiophysics 1949" is the first. Work is is hand on the following films:—

- "Caulking Compounds" (colour).
- "The Division of Forest Products—1950".
- "Better Grades and Ditches".
- "The Origin and Control of Salting".
- "Northern Australia Regional Survey Part 3—Ord-Victoria Rivers Area".
- A film dealing with the Division of Metrology.

The Section has kept in close touch with the Film Division of the Department of Information, which is now engaged in the production of the first of a series of films portraying the achievement of Australian scientific research and intended for release to the theatre circuits. This production will be concerned with the work of the Division of Entomology on the control of insect pests.

(f) *Central Information Service Activities.*—(i) *Dissemination of Information from Overseas.*—The Information Service has now been responsible for the handling of overseas material for two years, and the experience gained over this period has resulted in a better appreciation of the interests and requirements of Australian scientific workers, which in turn is resulting in further requests for information on other matters which would not be readily available through the normal channels. As a result, extensive mailing lists are being compiled, so that material received is made available on the widest possible basis, to those interested.

As a general principle, material received is recorded and abstracted, and abstract lists showing the final location of the material are sent out to organizations to whom it will be of value; but when it has been found that reports from a particular overseas organization are of special interest to local scientists, as shown by requests for loans, steps are taken to ascertain whether additional copies can be procured for distribution in Australia.

The Information Service has also made every effort to facilitate the flow of Australian reports in exchange. As well as putting Australian scientists into direct touch with their opposite numbers overseas, this has the advantage that future requests for material are granted more readily. It has been found that these exchanges are in fact welcomed by both parties, and the number in operation is steadily increasing.

Some idea of the volume of material being handled is conveyed by the following figures:—30 Overseas Unpublished Information Accessions Lists were prepared and issued to extensive mailing lists; 43 special lists were prepared and sent to a total of about 2,000 persons; about 1,500 items received from the Liaison Offices overseas were handled and distributed.

(ii) *War-time Research Reports from Overseas.*—This project, commenced in 1946, is still under way but naturally the volume of requests received has slackened off considerably. Approximately 200 reports were procured and supplied during the year.

(iii) *Declassification of Reports of Australian War-time Research.*—Action has been continued on the declassification of these reports and arrangements have been made for the transfer of reports which cannot be declassified to the library of Defence Research Laboratories.

(g) *Commonwealth Agricultural Bureaux.*—Preparations for the C.A.B. Review Conference, held in London in June-July, 1950, have occupied an important place in the Liaison Officer's activities during the year. A meeting of the Official Correspondents with the Liaison Officer was held in May to discuss the available Review Conference papers and to assist in formulating Australian policy on matters to be discussed at the Conference. The Australian delegation to the Review Conference was led by Dr. I. Clunies Ross, Chairman of the Organization.

All Commonwealth Agricultural Bureaux publicity work in Australia is now the responsibility of the Liaison Officer and is done in consultation with Official Correspondents. Every opportunity is taken to bring the information facilities provided by C.A.B. to the attention of Australian research and extension workers.

The Australian lists for the "List of Research Workers in Agriculture and Forestry in the British Commonwealth" have been revised and checked and will appear in the 1950 edition, now in press. A supplement will list agricultural and forestry research stations in the British Commonwealth.

### 3. LIBRARIES.

There have been no major changes in any matters of importance to the Library during the past year. The publication of the Organization's three new journals, the *Australian Journal of Agricultural Research,* the *ustralian Journal of Applied Science*, and the *Ausralian Journal of Marine and Freshwater Research*, as again stimulated exchange, and a gratifying number f offers of further publications for the Library in xchange for these new journals is being received.

In addition to publications received by exchange, ubscriptions have been accepted by some 50 of the nore important Russian scientific and technical ournals covering all branches of science. Although here are a few missing numbers, they are mostly coming o hand satisfactorily.

In the last Report it was recorded that an attempt was being made to find a really satisfactory method of ard duplication by mechanical means. It cannot be aid that this problem has yet been satisfactorily solved, although in some of the smaller libraries a simple flat-bed duplicator is being used to take off as many copies of the cards as are required, as well as copies of the accession list, from the one typing.

The member of the Library staff who went overseas in 1948 wrote a comprehensive report which has now appeared under the title "Special Library Practice, Report on a Visit to Special Libraries in England, France, Canada, and the United States of America in 1948". Judging by the demand for copies, this report is proving of considerable interest to librarians both here and abroad. The report takes the various techniques and processes of importance to special librarians one by one and discusses and compares the English and American practices.

Copies of the revised edition of the *Catalogue of Scientific and Technical Periodicals in the Libraries of Australia* should be available early in 1951. It is not intended that the appearance of this revised edition will end all work on the Catalogue. It has been arranged for a member of the staff to be always available to maintain a permanent Catalogue, in card form, of the library holdings of scientific and technical periodicals throughout Australia. Supplementary lists to the revised edition will be prepared and published, probably at regular intervals, and the necessity for preparing further revised editions in the years to come will be kept in mind. At the present time, work is concentrated on a list of journals which commenced publication since the close of the entries for the revised edition, i.e. since January, 1946. This supplementary list will probably be available for distribution very soon after the completed revised edition appears. The work of the Catalogue will be under the guidance of a Committee on which it is hoped to have representative librarians from each of the States, and also perhaps one or two non-librarian members who can put the point of view of the users of the Catalogue.

### 4. Overseas Liaison Offices.

The Organization maintains Scientific Liaison Offices in London and Washington. These form constituent units of the British Commonwealth of Nations Scientific Office (London) and the British Commonwealth Scientific Office (North America) respectively. These joint offices provide common facilities for Scientific Liaison Officers from the different Dominions to work together in London and Washington.

The C.S.I.R.O. Liaison Offices were originally set up during the war for the collection of information on radar and similar subjects. They now serve a number of important functions which include the carrying out of inquiries for C.S.I.R.O. Divisions and Sections, the location and collection of unpublished reports, and the general facilitating of the interchange of information. They also act as bases for C.S.I.R.O. officers overseas and a point of contact with research students. In addition, they procure specialized equipment and apparatus and generally act as a link for the Organization with scientific work in the United Kingdom and North America.

## XXXII. PERSONNEL OF COUNCIL AND COMMITTEES.

### 1. Executive.

I. Clunies Ross, D.V.Sc. (*Chairman*).
F. W. G. White, M.Sc., Ph.D. (*Chief Executive Officer*).
S. H. Bastow, D.S.O., B.Sc., Ph.D.
H. J. Goodes, B.A.
A. B. Ritchie, M.A.

### 2. Advisory Council.

*Chairman.*

Sir David Rivett, K.C.M.G., M.A., D.Sc., F.R.S.

*Executive.*

(*See* above).

*Chairmen of State Committees.*

New South Wales—A. J. Gibson, M.E.
Victoria—R. S. Andrews, D.Sc.
Queensland—A. F. Bell, B.Sc.
South Australia—Sir Kerr Grant, M.Sc.
Western Australia—Professor E. J. Underwood, B.Sc. (Agric.), Ph.D.
Tasmania—S. L. Kessell, M.Sc.

*Co-opted Members.*

Professor J. P. Baxter, O.B.E., B.Sc., Ph.D.
D. T. Boyd
N. K. S. Brodribb, C.B.E., F.R.I.C
Sir Harry Brown, C.M.G., M.B.E.
Professor F. M. Burnet, F.R.S., M.D., Ph.D.
W. S. Kelly.
E. H. B. Lefroy.
Sir John Madsen, B.E., D.Sc.
Professor D. M. Myers, D.Sc.
G. B. O'Malley, B.Met.E.
Professor S. M. Wadham, M.A.
Professor J. G. Wood, PhD., D.Sc.
C. E. Young, D.S.O.

### 3. State Committees.

*New South Wales.*

A. J. Gibson, M.E (*Chairman*).
C. J. Mulholland, B.Sc.
R. J. Noble, B.Sc.Agr., M.Sc., Ph.D.
A. R. Penfold.
Professor W. L. Waterhouse, M.C., B.Sc.Agr.
Professor J. D. Stewart, B.V.Sc.
Sir Frederick McMaster.
R. P. Okeden.
The Hon. Sir Norman Kater, M.L.C., M.B., Ch.M.
Emeritus Professor R. D. Watt, M.A., B.Sc.
J. Merrett.
W. R. Hebblewhite, B.E.
C. M. Williams.
J. G. Peake.
Professor Sir Henry Barraclough, K.B.E., V.D., B.E., M.M.E.
O. McL. Falkiner, M.L.C.
J. N. Briton, B.Sc., B.E.
F. L. S. Hudson.
J. P. Tivey, B.A., B.Sc., B.E.
Sir Harry Brown, C.M.G., M.B.E.
Sir John Madsen, B.E., D.Sc.
Professor J. P. Baxter, O.B.E., B.Sc., Ph.D.
Professor D. M. Myers, D.Sc.

*Victoria.*

R. S. Andrews, D.Sc. (*Chairman*).
H. A. Mullett, B.Agr.Sc.
W. Baragwanath.
G. G. Jobbins.
Professor J. S. Turner, M.A., Ph.D., M.Sc.
Professor P. MacCallum, M.C., M.A., M.Sc., M.B., Ch.B.
Professor J. N. Greenwood, D.Sc., M.Met.E.
W. E. Wainwright.

L. J. Weatherley, M.A.
H. Herman, D.Sc., M.M.E., B.C.E.
Sir Herbert Gepp.
Sir Dalziel Kelly, LL.B.
Sir Russell Grimwade, B.Sc.
Professor E. S. Hills, D.Sc., Ph.D., D.I.C.
Emeritus Professor H. A. Woodruff, B.Sc.
J. R. S. Cochrane, B.Sc.
Professor E. J. Hartung, D.Sc.
N. K. S. Brodribb, C.B.E.
Professor F. M. Burnet, M.D., Ph.D., F.R.S.
Professor S. M. Wadham, M.A.
Sir David Rivett, K.C.M.G., M.A., D.Sc., F.R.S.
D. T. Boyd.
G. B. O'Malley, B.Met.E.

*Queensland.*

A. F. Bell, M.Sc., D.I.C. (*Chairman*).
W. M. McLean, M.C.
R. Veitch, B.Sc.Agr., B.Sc.For.
Professor T. G. H. Jones, D.Sc., Ph.D
Professor D. A. Herbert, D.Sc.
J. F. Meynink.
J. McCann.
M. C. Urquhart, M.Sc.
V. G. Grenning.
A. McCulloch, M.E.
C. R. Paterson, B.E.
P. B. Newcomen.
J. L. Wilson.
J. Michelmore.
Professor L. J. H. Teakle, M.S., B.Sc.(Agric.), Ph.D.
R. J. S. Muir.
R. J. Donaldson, D.S.O., B.C.E.
C. E. Young, D.S.O.

*South Australia.*

Sir Kerr Grant, M.Sc. (*Chairman*).
W. J. Spafford.
S. B. Dickinson, M.Sc.
S. B. Shiels.
Professor T. Harvey Johnston, M.A., D.Sc.
Professor J. A. Prescott, D.Sc.
Professor M. L. Mitchell, M.Sc.
Sir James Gösse.
F. T. Perry.
A. J. Allen.
L. K. Ward, B.A., B.E., D.Sc.
Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.R.S.
A. R Callaghan, C.M.G., B.Sc., B.Sc.Agr., D.Phil.
H. R. Marston, F.R.S.
C. Haselgrove.
F. W. Moorhouse, M.Sc.
W. S. Kelly.
Professor J. G. Wood, Ph.D., D.Sc.

*Western Australia.*

Professor E. J. Underwood, B.Sc.(Agric.), Ph.D. (*Chairman*).
H. P. Rowledge.
A. L. McKenzie Clark, L.V.Sc.
T. N. Stoate, M.Sc.
Professor A. D. Ross, M.A., D.Sc.
Professor E. de Courcy Clarke, M.A.
B. Meecham.
A. L. B. Lefroy.
F. G. Brinsden.
Professor N. S. Bayliss, B.A., B.Sc., Ph.D.
R. B. Williamson.
W. G. Burges.
Professor G. A. Currie, D.Sc., B.Agr.Sc.
G. L. Sutton, D.Sc.Agr.
Professor H. Waring, D.Sc.
H. Bowley.
G. K. Baron-Hay, M.C., B.Sc.(Agric.).
P. H. Harper, B.A.
E. H. B. Lefroy.

*Tasmania.*

S. L. Kessell, M.Sc. (*Chairman*).
A. H. Crane.
A. W. Knight, B.Sc., M.E., B.Com.
F. W. Hicks.
J. Pearson, D.Sc.
Professor Alan Burn, M.Sc., B.E.
D. O. Meredith.
F. H. Peacock.
H. B. Somerset, M.Sc.
Sir Rupert Shoobridge, M.L.C.
L. R. Benjamin.
F. B. Richardson, M.A.
F. H. Foster, B.C.E.
Keith Brodribb.
T. A. Frankcomb.
N. F. Kirby, B.E.

### 4. COMMITTEE OF REVIEW—AGRICULTURAL AND PASTORAL PROBLEMS.

L. B. Bull, D.V.Sc., Division of Animal Health and Production, C.S.I.R.O. (*Chairman*).
B. T. Dickson, B.A., Ph.D., Division of Plant Industry, C.S.I.R.O.
H. R. Marston, F.R.S., Division of Biochemistry and General Nutrition, C.S.I.R.O.
J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
A. J. Nicholson, D.Sc., Division of Entomology, C.S.I.R.O.
I. Clunies Ross, D.V.Sc., C.S.I.R.O.
H. C. Forster, M.Agr.Sc., Ph.D., C.S.I.R.O.
W. Ives, M.Ec., A.I.C.A., C.S.I.R.O. (*Secretary*).

### 5. COMMONWEALTH RESEARCH STATION, MERBEIN—CONSULTATIVE COMMITTEE.

Professor J. A. Prescott, D.Sc., Waite Agricultural Research Institute, University of Adelaide (*Chairman*).
J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
L. A. T. Ballard, Ph.D., Division of Plant Industry, C.S.I.R.O.
C. Barnard, D.Sc., Division of Plant Industry, C.S.I.R.O.
P. Malloch, Commonwealth Dried Fruits Control Board.
E. J. Casey, Commonwealth Dried Fruits Control Board.
J. R. Gordon, representing Advisory Committee.
A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein (*Secretary*).

### 6. COMMONWEALTH RESEARCH STATION, MERBEIN—ADVISORY COMMITTEE.

J. R. Gordon, Citrus Growers' Association, Merbein (*Chairman*).
J. A. Aird, B.Sc., B.Agr.Sc., Dip. Com., Commissioner, State Rivers and Water Supply Commission, Victoria.
L. W. Andrews, Waikerie, South Australia.
P. T. Byrnes, Woorinen, Victoria.
A. E. Cameron, Red Cliffs Settlement.
E. J. Casey, representing Consultative Committee.
D. W. Cockcroft, Nyah-Woorinen Inquiry Committee.
C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria.
W. B. Hawson, First Mildura Irrigation Trust.
A. E. Hazel, Dried Fruits Association, Red Cliffs.
S. Heaysman, Coomealla, New South Wales.
W. Heaysman, Cardross Progress Association.
H. Jackson, Wakool Land-use Committee.
J. A. Lochhead, Mildura Shire Council.
A. R. McDougall, Merbein.
P. Malloch, representing Consultative Committee.

C. Polkinghorne, Nyah-Woorinen Inquiry Committee.

G. Savage, Department of Agriculture, New South Wales.

L. Showell, Renmark Irrigation Trust.

. Stevens, Nyah-Woorinen Inquiry Committee.

. G. Strickland, M.Agr.Sc., Department of Agriculture, South Australia.

P. Taylor, Curlwaa, New South Wales.

. Weste, Renmark, South Australia.

. C. Winterbottom, Mildura Packers' Association.

. V. Lyon, M.Agr.Sc., Commonwealth Research Sta-Station, C.S.I.R.O., Merbein (*Secretary*).

### 7. WAKOOL LAND-USE COMMITTEE.

. Varcoe-Cocks, Wakool Shire Council (*Chairman*).

. V. Lyon, M.Agr.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.

. I. Bolton, Water Conservation and Irrigation Commission, New South Wales.

. F. Diamond, Rural Bank of New South Wales.

. Howe, Rural Bank of New South Wales.

. A. Crawford, Department of Agriculture, New South Wales.

. M. Savage, H.D.A., Department of Agriculture, New South Wales.

K. Wood, representing Wakool District Landowners' Executive.

). Thomas, representing Wakool District Landowners' Executive.

V. R. A. Smith, representing Wakool District Landowners' Executive.

F. J. Hollins, representing Wakool District Landowners' Executive.

R. W. Prunster, B.Sc. (Agric.), Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin.

H. Jackson, representing Wakool District Landowners' Executive (*Secretary*).

### 8. IRRIGATION RESEARCH STATION, GRIFFITH—CONSULTATIVE COMMITTEE.

B. T. Dickson, B.A., Ph.D., Division of Plant Industry, C.S.I.R.O. (*Chairman*).

Professor J. A. Prescott, D.Sc., Waite Agricultural Research Institute, University of Adelaide.

J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.

H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.

V. C. Williams, representing Irrigation Research and Extension Committee.

E. S. West, B.Sc., M.S., Irrigation Research Station, C.S.I.R.O., Griffith (*Secretary*).

### 9. IRRIGATION RESEARCH AND EXTENSION COMMITTEE (MURRUMBIDGEE IRRIGATION AREAS).

V. C. Williams, Griffith Producers' Co-operative Company Limited (*Chairman*).

R. R. Pennefather, M.I.A. Extension Organizer, Department of Agriculture, New South Wales.

H. J. Hynes, D.Sc.Agr., M.S., Department of Agriculture, New South Wales.

A. H. Skepper, H.D.A., Department of Agriculture, New South Wales.

B. M. Savage, H.D.A., Department of Agriculture, New South Wales.

E. S. West, B.Sc., M.S., Irrigation Research Station, C.S.I.R.O., Griffith.

A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.

R. W. Prunster, B.Sc.(Agric.), Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin.

E. R. Iredale, Rural Bank of New South Wales.

F. J. McKirdy, Rural Bank of New South Wales.

H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.

H. Mallaby, H.D.A., Water Conservation and Irrigation Commission, New South Wales.

Professor J. R. A. McMillan, D.Sc.Agr., M.S., University of Sydney.

E. S. Clayton, H.DA., Soil Conservation Service, New South Wales.

K. I. Bridge, H.D.A., Soil Conservation Service, New South Wales.

H. J. Williams, Leeton Co-operative Cannery Limited.

W. Arbuckle, Leeton Fruitgrowers' Co-operative Society Limited.

A. D. McKellar, Rice Growers' Association, Leeton.

J. H. Reilly, Rice Growers' Association, Yenda.

T. Darchy, Rice Growers' Association, Murrami.

J. E. Morphett, Vegetable Growers' Association.

F. R. Polkinghorne, District Council of Extension Groups, Griffith.

J. Woodside, Large Area Extension Groups, Griffith.

G. S. Denne, District Council of Extension Groups, Leeton.

R. St. C. Young, Large Area Extension Groups, Yanco.

P. F. Stanton, Yanco Experiment Farm, Yanco.

J. O. Doyle, Rice Marketing Board, New South Wales.

A. F. Gurnett-Smith, B.Agr.Sc., Q.D.D., Department of Agriculture, New South Wales.

Representative of Yenda Producers' Co-operative Society Limited to be appointed.

### 10. REGIONAL PASTORAL CENTRE, DENILIQUIN—TECHNICAL COMMITTEE.

B. T. Dickson, B.A., Ph.D., Division of Plant Industry, C.S.I.R.O.

J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.

L. B. Bull, D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.

H. R. Marston, Division of Biochemistry and General Nutrition, C.S.I.R.O.

J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.

T. J. Marshall, M.Ag.Sc., Ph.D., Division of Soils, C.S.I.R.O.

A. J. Vasey, B.Agr.Sc., Division of Animal Health and Production, C.S.I.R.O.

E. S. West, B.Sc., M.S., Irrigation Research Station, C.S.I.R.O., Griffith.

A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.

O. McL. Falkiner, Boonoke Station, Conargo.

J. N. Whittet, H.D.A., Department of Agriculture, New South Wales.

R. W. Prunster, B.Sc. (Agric.), Division of Plant Industry, C.S.I.R.O. (*Secretary*).

### 11. REGIONAL PASTORAL CENTRE, ARMIDALE—TECHNICAL ADVISORY COMMITTEE.

L. B. Bull, D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.

B. T. Dickson, B.A., Ph.D., Division of Plant Industry, C.S.I.R.O.

J. G.Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.

D. A. Gill, M.R.C.V.S., D.V.S.M., Division of Animal Health and Production, C.S.I.R.O.

G. Edgar, B.V.Sc., Department of Agriculture, New South Wales.

J. N. Whittet, H.D.A., Department of Agriculture, New South Wales.

I. L. Johnstone, B.V.Sc., Division of Animal Health and Production, C.S.I.R.O. (*Secretary*).

### 12. REGIONAL PASTORAL CENTRE, ARMIDALE—CONSULTATIVE COMMITTEE.

D. A. Gill, M.R.C.V.S., D.V.S.M., Division of Animal Health and Production, C.S.I.R.O. (*Chairman*).

R. B. Madgwick, M.Ec., D.Phil., New England University College.
A. H. Voisey, D.Sc., New England University College.
A. G. Brett, Graziers' Association of New South Wales.
J. A. Nivison, Graziers' Association of New South Wales.
H. F. White, Graziers' Association of New South Wales.
D. P. Macansh, Northern New South Wales Farmers' Union.
A. W. Weller, Northern New South Wales Farmers' Union.
Sir Hugh Croft, Council of Advice to the Pasture Protection Boards, New South Wales.
S. Payne, Council of Advice to the Pasture Protection Boards, New South Wales.
G. Edgar, B.V.Sc., Department of Agriculture, New South Wales.
J. N. Whittet, H.D.A., Department of Agriculture, New South Wales.
L. W. McLennan, B.Sc.Agr., New England Regional Development Committee.
J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.
I. L. Johnstone, B.V.Sc., Division of Animal Health and Production, C.S.I.R.O. (*Secretary*).

### 13. "Gilruth Plains" Technical Committee.

L. B. Bull, D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.
B. T. Dickson, B.A., Ph.D., Division of Plant Industry, C.S.I.R.O.
C. M. Donald, M.Ag.Sc., Division of Plant Industry, C.S.I.R.O.
R. B. Kelley, D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.
W. A. T. Summerville, D.Sc., Queensland Department of Agriculture and Stock.
W. Webster, B.V.Sc., Queensland Department of Agriculture and Stock.
J. F. Kennedy, M.Agr.Sc., Division of Animal Health and Production, C.S.I.R.O. (*Secretary*).

### 14. Joint Blowfly Control Committee.

(Appointed as a means of co-ordinating the activities of the New South Wales Department of Agriculture, the Queensland Department of Agriculture and Stock, and the Organization.)

L. B. Bull, D.V.Sc., Division of Animal Health and Production, C.S.I.R.O. (*Chairman*).
A. J. Nicholson, D.Sc., Division of Entomology, C.S.I.R.O.
G. Edgar, B.V.Sc., Glenfield Veterinary Research Station, Department of Agriculture, New South Wales.
H. G. Belschner, D.V.Sc., Department of Agriculture, New South Wales.
T. McCarthy, Department of Agriculture, New South Wales.
W. Webster, B.V.Sc., Department of Agriculture and Stock, Queensland.
F. H. S. Roberts, D.Sc., Division of Animal Health and Production, C.S.I.R.O.
D. A. Gill, M.R.C.V.S., D.V.S.M., Division of Animal Health and Production, C.S.I.R.O. (*Secretary*).

### 15. Joint Veterinary Parasitology Committee.

W. Webster, B.V.Sc., Department of Agriculture and Stock, Queensland (*Chairman*).
J. Legg, D.V.Sc., Department of Agriculture and Stock, Queensland.
F. H. S. Roberts, D.Sc., Division of Animal Health and Production, C.S.I.R.O.
L. F. Hitchcock, M.Sc., Division of Entomology, C.S.I.R.O.
Miss H. F. Todd, C.S.I.R.O. (*Secretary*).

### 16. Queensland Producers' Animal Industry Committee.

W. I. McLean, Queensland United Graziers' Association (*Chairman*).
F. M. Bell, Queensland United Graziers' Association.
C. R. S. Smith, Queensland United Graziers' Association.
R. M. Bell, Queensland United Graziers' Association.
G. Woodburn, Queensland United Graziers' Association.
T. N. Pownall, Queensland United Graziers' Association.
J. F. Meynink, Queensland United Graziers' Association.
R. S. Wilson, Queensland United Graziers' Association.
J. L. Wilson, Queensland United Graziers' Association.
W. A. Gunn, Queensland United Graziers' Association.
W. G. Jones, Queensland United Graziers' Association.
C. H. Jamieson, Queensland Dairymen's State Council.
W. Webster, B.V.Sc., Department of Agriculture and Stock, Queensland.
M. White, M.Sc., Ph.D., Department of Agriculture and Stock, Queensland.
J. Legg, D.V.Sc., Department of Agriculture and Stock, Queensland.
G. R. Moule, B.V.Sc., Department of Agriculture and Stock, Queensland.
A. F. Bell, M.Sc., D.I.C., Department of Agriculture and Stock, Queensland.
F. H. S. Roberts, D.Sc., Division of Animal Health and Production, C.S.I.R.O.
L. F. Hitchcock, M.Sc., Division of Entomology, C.S.I.R.O.
T. B. Paltridge, B.Sc., Division of Plant Industry, C.S.I.R.O.
A. R. Riddle, A.B., M.S., Division of Food Preservation and Transport, C.S.I.R.O.
Professor W. V. Macfarlane, M.A., M.B., Ch.B., University of Queensland.
R. J. Donaldson, D.S.O., B.C.E., Brisbane.
Miss H. F. Todd, C.S.I.R.O. (*Secretary*).

### 17. Advisory Committee on Fruit Cool Storage Investigations in New South Wales.

C. G. Savage, Department of Agriculture, New South Wales (*Chairman*).
H. Broadfoot, Department of Agriculture, New South Wales.
Professor N. A. Burges, M.Sc., Ph.D., Department of Botany, University of Sydney.
J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.
R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

### 18. Committee for Co-ordination of Fruit and Vegetable Storage Research.

W. M. Carne, Department of Commerce and Agriculture, Melbourne (*Chairman*).
S. M. Sykes, B.Sc.Agr., Department of Agriculture, New South Wales.
C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria.
A. G. Strickland, M.Agr.Sc., Department of Agriculture, South Australia.
T. D. Raphael, M.A., Dip.Hort.(Cambridge), Department of Agriculture, Tasmania.
R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.
D. Martin, B.Sc., Division of Plant Industry, C.S.I.R.O.
S. A. Trout, M.Sc., Ph.D., Department of Agriculture and Stock, Queensland.
T. C. Miller, B.Sc., Department of Agriculture, Western Australia.

. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

### 19. Consultative Committee on Food Investigations and Standards.

. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O. (*Chairman*).

. W. Hicks, B.A., B.Sc., Division of Food Preservation and Transport, C.S.I.R.O.

R. F. Turnbull, B.E., Division of Forest Products, C.S.I.R.O.

G. Loftus Hills, B.Agr.Sc., Dairy Research Section, C.S.I.R.O.

W. M. Carne, Department of Commerce and Agriculture, Melbourne.

W. J. Wiley, D.Sc., Department of Commerce and Agriculture, Melbourne.

H. R. Tinney, B.V.Sc., Department of Commerce and Agriculture, Melbourne.

R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

### 20. Committee for Co-ordination of Research on Fruit and Vegetable Processing.

J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O. (*Chairman*).

L. J. Lynch, B.Agr.Sc., Division of Food Preservation and Transport, C.S.I.R.O.

J. Shipton, B.Sc.Agr., Division of Food Preservation and Transport, C.S.I.R.O.

J. D. Bryden, H.D.A., New South Wales Department of Agriculture.

A. C. Orman, H.D.A., New South Wales Department of Agriculture.

H. R. Richardson, B.Sc.Agr., New South Wales Department of Agriculture.

E. G. Hallsworth, B.Sc., Ph.D., School of Agriculture, University of Sydney.

R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

### 21. Dried Fruits Processing Committee.

A. G. Strickland, M.Agr.Sc., Department of Agriculture, South Australia (*Chairman*).

C. G. Savage, Department of Agriculture, New South Wales.

W. R. Jewell, M.Sc., B.Met., F.R.I.C., Department of Agriculture, Victoria.

W. M. Carne, Department of Commerce and Agriculture, Melbourne.

J. M. Davidson, B.V.Sc., Department of Commerce and Agriculture, Melbourne.

A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.

E. C. Orton, B.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.

J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.

D. G. Quinn, Department of Agriculture, Victoria.

B. G. Coombe, B.Agr.Sc., Department of Agriculture, South Australia (*Secretary*).

### 22. Advisory Committee on Fruit Storage—Investigations in Victoria.

C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria (*Convenor and Secretary*).

S. Fish, M.Agr.Sc., Department of Agriculture, Victoria.

R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.

W. J. Scott, B.Agr.Sc., Division of Food Preservation and Transport, C.S.I.R.O.

### 23. Mildura District Dried Vine Fruits Processing Committee.

A. R. Hampton, representing Mildura Packers' Association (*Chairman*).

A. E. Hazel, Dried Fruits Associatin, Red Cliffs.

W. Heaysman, representing Merbein Advisory Committee.

W. R. Jewell, M.Sc., B.Met., F.R.I.C., Department of Agriculture, Victoria.

N. A. Johnson, Irymple, Victoria.

A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.

K. H. C. McCallum, Red Cliffs, Victoria.

A. R. McDougall, Merbein, Victoria.

S. R. Mansell, Mildura, Victoria.

B. Bromley, Red Cliffs, Victoria.

E. C. Orton, B.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein (*Secretary*).

### 24. Advisory Committee on Red-legged Earth Mite Investigations, Western Australia.

E. H. B. Lefroy (*Chairman*).

C. F. Jenkins, B.A., Department of Agriculture, Western Australia.

I. Thomas, Department of Agriculture, Western Australia.

Professor E. J. Underwood, B.Sc. (Agr.), Ph.D., University of Western Australia.

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M. M. H. Wallace, B.Sc., Division of Entomology, C.S.I.R.O.

R. P. Roberts, M.Sc. (Agric.) (*Secretary*).

### 25. Flax Research Advisory Committee.

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I. H. Boas, M.Sc., Melbourne.

R. B. Hogg, representing the Australian flax spinners.

A. B. Weigall, representing the growers.

### 26. Committee on Oenological Research.

Professor J. A. Prescott, D.Sc., representing C.S.I.R.O. (*Chairman*).

C. Haselgrove, representing the Federal Viticultural Council.

Professor J. B. Cleland, M.D., Ch.M., representing the University of Adelaide.

H. R. Haselgrove, representing the Australian Wine Board.

### 27. Fuel Research Advisory Committee.

R. S. Andrews, D.Sc., Melbourne (*Chairman*).

Professor T. G. Hunter, B.Sc., Ph.D., University of Sydney.

Professor C. E. Marshall, Ph.D., University of Sydney.

S. B. Dickinson, M.Sc., Department of Mines, South Australia.

L. J. Rogers, M.Sc., B.E., Department of Supply and Development.

C. R. Kent, B.Sc., Ph.D., D.I.C., Joint Coal Board.

R. P. Donnelly, Government Chemical Laboratory, Western Australia.

J. R. Duggan, B.Sc., B.E., Colonial Gas Association, Queensland.

H. R. Brown, B.Sc., Min.Eng., Coal Research Section, C.S.I.R.O.

F. W. G. White, M.Sc., Ph.D., C.S.I.R.O.

I. W. Wark, D.Sc., Ph.D., Division of Industrial Chemistry, C.S.I.R.O.

A. B. Edwards, D.Sc., Ph.D., Mineragraphic Investigations, C.S.I.R.O.

G. B. Gresford, B.Sc., C.S.I.R.O. (*Secretary*).

### 28. Melbourne Ore-dressing Sub-committee.

H. Hey, Electrolytic Zinc Co. Ltd., Melbourne (*Chairman*).

W. Baragwanath, Melbourne.

G. B. O'Malley, B.Met.E., Melbourne.

W. J. Rose, B.M.E., Commonwealth Tariff Board.

Associate Professor H. H. Dunkin, B.Met.E., School of Metallurgy, University of Melbourne.
R. B. Mills, B.Sc., Electrolytic Zinc Co. Ltd., Melbourne.
M. A. E. Mawby, F.S.T.C., Zinc Corporation Ltd., Melbourne.
K. S. Blaskett, B.E. (*Secretary*).

### 29. Kalgoorlie Ore-dressing Sub-committee.

J. S. Foxall, B.E., Department of Mines, Western Australia.
F. G. Brisden, Australasian Institute of Mining and Metallurgy, Western Australia.
R. A. Hobson, B.Sc., School of Mines, Kalgoorlie, Western Australia.
J. R. Hylton, Great Boulder Pty. Gold Mines Ltd., Fimiston, Western Australia

### 30. Mineragraphic Committee.

Emeritus Professor E. W. Skeats, D.Sc., Melbourne.
W. E. Wainwright, A.S.A.S.M., Australasian Institute of Mining and Metallurgy.

### 31. Tracer Element Research Committee.

C. E. Eddy, D.Sc., Department of Health.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.O.
F. G. Nicholls, M.Sc., C.S.I.R.O. (*Secretary*).

### 32. Electrical Research Board.

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R. Liddelow, Electricity Supply Association of Australia.
V. J. F. Brain, Electricity Supply Association of Australia.
Professor D. M. Myers, B.Sc., D.Sc.Eng., University of Sydney.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.O.
F. J. Lehany, M.Sc., Division of Electrotechnology, C.S.I.R.O.
F. G. Nicholls, M.Sc., C.S.I.R.O. (*Conjoint Secretary*).
R. C. Richardson, B.E., Division of Electrotechnology, C.S.I.R.O. (*Conjoint Secretary*).

### 33. Radio Research Board.

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Lieutenant-Commander A. Brook, R.N.
Lieutenant-Colonel E. G. Foster, Director of Signal and Radar Equipment, A.M.F.
Wing-Commander J. W. Reddrop, Director of Telecommunications and Radar, R.A.A.F.
R. v.d. R. Woolley, M.A., M.Sc., Ph.D., Mt. Stromlo Observatory.
Professor H. C. Webster, D.Sc., Ph.D., University of Queensland.
Professor L. G. H. Huxley, M.A., D.Phil., University of Adelaide.
E. P. Wright, B.Sc., Postmaster-General's Department.
E. G. Bowen, O.B.E., M.Sc., Ph.D., Division of Radiophysics, C.S.I.R.O.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.O.
F. G. Nicholls, M.Sc., C.S.I.R.O. (*Secretary*).

### 34. Meteorological Research Consultative Committee.

R. v.d. R. Woolley, M.A., M.Sc., Ph.D., Mt. Stromlo Observatory (*Chairman*).
Professor Sir John Madsen, B.E., D.Sc., University of Sydney.
H. N. Warren, Commonwealth Meteorological Service.
F. Loewe, Ph.D., University of Melbourne.
E. G. Bowen, O.B.E., M.Sc., Ph.D., Division of Radiophysics, C.S.I.R.O.
C. H. B. Priestley, M.A., C.S.I.R.O.
G. B. Gresford, B.Sc., C.S.I.R.O. (*Secretary*).

### 35. Aviation Radio Research Committee.

E. G. Bowen, O.B.E., M.Sc., Ph.D., Division of Radiophysics, C.S.I.R.O. (*Chairman*).
R. M. Badenach, Department of Civil Aviation.
C. S. Wiggins, Department of Civil Aviation.
Wing-Commander J. W. Reddrop, Director of Telecommunications and Radar, R.A.A.F.
M. H. Myers, Qantas Empire Airways Ltd.
R. J. Cains, Australian National Airways Pty. Ltd.
F. E. Coate, Australian National Airlines Commission.
E. P. Wright, B.Sc., Postmaster-General's Department.
Captain L. E. Morey, Australian Air Pilots' Association.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.O.
F. G. Nicholls, M.Sc., C.S.I.R.O. (*Secretary*).

### 36. Building Research Committee.

I. Langlands, B.E.E., M.Mech.E., Building Research Section, C.S.I.R.O. (*Chairman*).
Professor J. A. L. Matheson, M.B.E., M.Sc., Ph.D., University of Melbourne.
T. J. Cavanagh, Sydney.
D. V. Isaacs, M.C.E., Department of Works and Housing.
O. A. Bayne, Department of Works and Housing.
R. E. Banks, Department of Works and Housing.
L. D. Wright, Department of Labour and National Service.
S. A. Clarke, B.E., Division of Forest Products, C.S.I.R.O.
W. F. Evans, B.Sc., Building Research Section, C.S.I.R.O. (*Secretary*).

### 37. Catalogue of Scientific and Technical Periodicals—Editorial Committee.

Leigh Scott, M.A., Librarian, University of Melbourne.
John Metcalfe, B.A., Principal Librarian, Public Library of New South Wales.
C. A. McCallum, B.A., Chief Librarian, Public Library, Melbourne.
Ellinor Archer, M.Sc., Chief Librarian, C.S.I.R.O.

## XXXIII. STAFF.

The following is a list of the staff of the Organization as at 30th June, 1950. The list does not include clerical staff, typists, laboratory assistants, and miscellaneous workers:—

### 1. Head Office.

(Head-quarters: 314 Albert-street, East Melbourne.)
Chairman—I. Clunies Ross, D.V.Sc.
Chief Executive Officer—F. W. G. White, M.Sc., Ph.D.
Executive Officer—S. H. Bastow, D.S.O., B.Sc., Ph.D.
Secretary—G. A. Cook, M.C., M.Sc., B.M.E.
Assistant Executive Officer—H. C. Forster, M.Agr.Sc., Ph.D.
Assistant Secretary—F. G. Nicholls, M.Sc.
Assistant Secretary—G. B. Gresford, B.Sc.
Assistant Secretary—W. Ives, M.Ec., A.I.C.A.
Assistant Secretary (Finance and Supplies)—M. G. Grace, A.I.C.A.
Senior Research Officer—D. T. C. Gillespie, M.Sc.
Research Officer—Miss J. Dunstone, B.Sc., Dip.Ed.
Architect—W. R. Ferguson, B.E.
Assistant to Architect—N. Schmidt.
Electrical and Mechanical Engineer—R. N. Morse, B.Sc., B.E.
Electrical Engineer—A. McLean, B.E.E.
*Editorial*—
  Editor—N. S. Noble, D.Sc.Agr., M.S., D.I.C.
  Senior Research Officer—R. W. Bond, B.Sc.
  Research Officer—Miss L. F. Plunkett, B.Sc.
  Research Officer—Miss M. Walkom, B.A.
*Library*—
  Chief Librarian—Miss E. Archer, M.Sc.

Librarian—Miss A. L. Kent.
Librarian—Miss F. V. Murray, M.Sc.
Librarian—Miss J. Conochie, B.Sc.
Assistant Librarian—Miss J. Rosenberg, B.A.
Assistant Librarian—Miss T. Koetsier, B.A.

*Accounts, Stores—*

Accountant—D. J. Bryant, A.F.I.A.
Sub-accountant—R. W. Viney, A.I.C.A., A.C.I.S.

*Orders and Transport—*

J. M. Derum.

*Staff—*

Staff and Industrial Officer—H. E. Waterman, A.F.I.A.
R. D. Elder.

*Records—*

P. Knuckey.

*Central Experimental Workshops—*

Engineer-in-Charge—F. G. Hogg, B.E.
Sectional Draughtsman—G. P. Ackroyd.

*Liaison Overseas—*

*London—*

Chief Scientific Liaison Officer—J. E. Cummins, B.Sc., M.S.
Research Officer—A. B. Hackwell, B.Agr.Sc.

*Washington—*

Senior Research Officer—T. C. Bell, B.Agr.Sc.

*Information Service—*

*Administration—*

Officer-in-Charge—C. M. Gray, O.B.E., M.Sc.
Technical Secretary—F. A. Priest, A.S.A.S.M.

*Information Section—*

Senior Research Officer—J. F. H. Wright, B.Sc.
Research Officer—Miss J. McL. Baldwin, B.Sc., Dip.Ed.
Research Officer—Miss S. M. Andrews, B.Sc.
Research Officer—G. J. Walker, M.Sc.
Research Officer—Miss M. G. McKay, B.Sc.
Overseas Information—Miss I. H. Robertson, M.Sc., D.A.C.

*Abstracting and Documentation Section—*

Research Officer—G. J. Wylie, B.A., B.Sc.
Indexer—Miss G. M. Lesslie, B.Sc.

*Translation Section—*

Senior Translator—A. L. Gunn.
Translator—E. Feigl, Ph.D.
Translator—E. W. Selman-Towt.
Translator—Mrs. M. Slade.
Translator—Miss P. A. Gibson, B.A.

*Ciné-Photographic Section—*

Research Officer—S. T. Evans, B.Sc.

*Commonwealth Agricultural Bureaux—*

Liaison Officer for Australia—A. B. Cashmore, M.Sc.

*Sydney Office—*

Research Officer—A. M. Andrews, B.Sc.
Translator—C. W. Wouters, D. ès L.

### 2. Secretaries of State Committees.

*New South Wales—*

A. M. Andrews, B.Sc., Phillip House, 119 Phillip-street, Sydney.

*Victoria—*

F. G. Nicholls, M.Sc., 314 Albert-street, East Melbourne.

*Queensland—*

Miss H. F. Todd, 113 Eagle-street, Brisbane.

*South Australia—*

J. Ward Walters, Division of Biochemistry and General Nutrition, University of Adelaide.

*Western Australia—*

R. P. Roberts, M.Sc.(Agric.), Department of Agriculture, Perth.

*Tasmania—*

D. Martin, B.Sc., "Stowell", Stowell-avenue, Hobart.

### 3. Division of Animal Health and Production.

(Head-quarters: Cr. Flemington-road and Park-street, Parkville, Melbourne.)

*At Divisional Head-quarters, Melbourne—*

Chief—L. B. Bull, D.V.Sc.
Divisional Secretary—A. J. Vasey, B.Agr.Sc.
Assistant Divisional Secretary—N. M. Tulloh, B.Agr.Sc.

*At Animal Health Research Laboratory, Melbourne—*

Assistant Chief of Division and Officer-in-Charge—A. W. Turner, O.B.E., D.Sc., D.V.Sc.
Principal Research Officer (bacteriology)—T. S. Gregory, B.V.Sc., Dip.Bact.
Principal Research Officer (pathology bacteriology, dairy cattle)—D. Murnane, D.V.Sc.
Senior Research Officer (bacteriology, beef cattle)—A. D. Campbell, L.V.Sc.
Senior Research Officer (physiology)—R. H. Watson, D.Sc.Agr.
Senior Research Officer (organic and immunochemistry)—A. T. Dann, M.Sc.
Senior Research Officer (chemical pathology and bacteriology)—A. T. Dick, M.Sc.
Research Officer (bacteriology, dairy cattle)—E. Munch-Petersen, M.Sc., B.A., M.I.F.
Research Officer (microbiological chemistry)—A. W. Rodwell, M.Sc., Ph.D.
Research Officer (chemical pathology and analytical chemistry)—J. B. Bingley, D.A.C.
Research Officer (bacteriology)—Miss C. E. Eales, B.Sc.
Research Officer (bacteriology)—Miss M. J. Monsbourgh, B.Sc. (on leave).
Research Officer (dairy cattle physiology)—H. G. Turner, B.Agr.Sc.
Research Officer (physiology)—G. Alexander, B.Agr.Sc. (on study leave).
Research Officer (physiology) — H. M. Radford, B.Sc.
Research Officer (clinical biochemistry) — Miss V. E. Hodgetts, B.Sc.
Research Officer (physiology)—J. S. McKenzie, B.Sc.
Technical Officer—M. W. Mules.
Technical Officer—E. Wold.
Technical Officer—A. E. Wright.
Technical Officer—J. J. Spencer.
Technical Officer—R. A. Fookes.
Technical Officer—N. E. Southern.
Librarian—Miss F. V. Murray, M.Sc. (part-time).

*Survey of Beef Cattle Production—*

Senior Research Officer—W. A. Beattie, B.A., LL.B. (N.Z.), M.A. (Cantab.).

*At Field Station, Werribee, Victoria—*

*Dairy Cattle Investigations—*

Technical Officer—L. C. Gamble.

*Poultry Breeding Investigations—*

Research Officer—F. Skaller, B.Agr.Sc., B.Com.
Research Officer—J. A. Morris, B.Sc.Agr.
Research Officer—G. W. Grigg, B.Sc.
Technical Officer—W. J. Lloyd.

*At F. D. McMaster Animal Health Laboratory, Sydney, New South Wales*—

Assistant Chief of Division and Officer-in-Charge—D. A. Gill, M.R.C.V.S., D.V.S.M.
Principal Research Officer (parasitology)—H. McL. Gordon, B.V.Sc.
Principal Research Officer (biochemistry)—M. C. Franklin, M.Sc., Ph.D.
Senior Research Officer (helminth physiology, parasitology)—W. P. Rogers, M.Sc., Ph.D.
Senior Research Officer (bacteriology)—D. F. Stewart, B.V.Sc., Dip.Bact.
Senior Research Officer (biochemistry)—C. R. Austin, M.Sc., B.V.Sc.
Research Officer (biochemistry)—R. L. Reid, B.Sc.Agr., Ph.D.
Research Officer (parasitology)—B. A. Forsyth, B.V.Sc.
Research Officer (biochemistry)—W. K. Warburton, LL.B., B.Sc.
Research Officer (physiology)—A. W. H. Braden, B.Sc.
Research Officer (helminth physiology, parasitology)—V. Massey, B.Sc. (abroad).
Research Officer (ectoparasites)—Miss T. M. Scott, B.Sc.
Research Officer (parasitology)—Miss P. M. Sambell, B.A.
Research Officer (helminth physiology, parasitology)—Miss H. B. Esserman, B.Sc.
Ian McMaster Research Scholar—P. R. Whitfield, B.Sc.
Technical Officer—H. A. Offord.
Technical Officer—F. J. Hamilton,
Technical Officer—H. V. Whitlock.
Technical Officer—P. B. Sutton.
Clerk—H. H. Wilson.
Librarian—Miss A. G. Culey, M.Sc.

*At Wool Biology Laboratory, Sydney, New South Wales*—

Officer-in-Charge (wool biology)—H. B. Carter, B.V.Sc.
Research Officer (wool biology)—Miss M. H. Hardy, M.Sc., Ph.D.
Research Officer (wool biology)—K. Ferguson, B.V.Sc. (abroad).
Research Officer (wool biology)—Miss P. Davidson, B.Sc.
Technical Officer—D. L. Hall.
Technical Officer—W. H. Clarke.

*Sheep Breeding Investigations*—

Research Officer—A. A. Dunlop, M.Agr.Sc., Ph.D.

*Cattle Breeding Investigations*—

Research Officer—D. F. Dowling, B.V.Sc., B.Sc., Ph.D.

*At Fleece Analysis Laboratory, Villawood, New South Wales*—

Officer-in-Charge (wool metrology)—N. F. Roberts, M.Sc.
Research Officer (wool metrology)—L. T. Wilson, B.Sc., A.A.C.I.
Technical Officer—Miss L. Folley.

*At Regional Pastoral Laboratory, Armidale, New South Wales.*—

Officer-in-Charge (parasitology, field studies)—I. L. Johnstone, B.V.Sc.
Research Officer (animal husbandry)—J. F. Barrett, B.V.Sc.
Research Officer (parasitology)—W. H. Southcott, B.V.Sc.
Research Officer (parasitology)—D. P. Clarke, B.Sc.
Technical Officer (overseer)—V. D. Prentice, O.B.E.
Technical Officer—R. J. Lewis.
Technical Officer—J. W. Carr.

*At F. D. McMaster Field Station, Badgery's Creek, New South Wales*—

Assistant Chief of Division and Officer-in-Charge (animal genetics)—R. B. Kelley, D.V.Sc.
Research Officer (sheep breeding)—R. H. Hayman, B.Agr.Sc.
Technical Officer—M. J. Kempfé.

*At Veterinary Parasitology Laboratory, Yeerongpilly, Queensland*—

Officer-in-Charge (parasitology)—F. H. S. Roberts, D.Sc.
Research Officer (parasitology)—P. H. Durie, B.Sc.
Research Officer (entomology, pathology)—R. S. Riek, B.V.Sc.
Technical Officer—R. K. Keith.

*Survey of Fine Wool Production*—

Senior Research Officer—J. H. Riches, B.Sc.Agr., Ph.D.

*At Food Preservation Research Laboratory, Cannon Hill, Queensland*—

Research Officer (carcass appraisal)—N. T. M. Yeates, B.Sc.Agr., Ph.D.

*At National Field Station, "Gilruth Plains", Cunnamulla, Queensland*—

Officer-in-Charge (sheep breeding)—J. F. Kennedy, M.Agr.Sc.
Technical Officer (overseer)—R. H. Fogg.
Technical Officer—P. H. G. Sheaffe.
Technical Officer—F. J. Willett.

*At Western Australian Department of Agriculture, Animal Health and Nutrition Laboratory, Nedlands, Western Australia*—

Research Officer (biochemistry)—A. B. Beck, M.Sc.

### 4. ATOMIC PHYSICS.

*At University of Melbourne*—

Research Officer—W. B. Lasich, M.Sc.
Research Officer—V. R. Prescott, B.Sc.
Technical Officer—D. R. Ellis.

*Tracer Elements Unit* (at Commonwealth X-Ray and Radium Laboratory, Melbourne)—

Principal Research Officer—T. H. Oddie, D.Sc., F. Inst.P.
Research Officer—A. M. Downes, M.Sc.
Research Officer—K. R. Lynn, B.Sc.

*At University of Tasmania*—

Research Officer—D. W. P. Burbury, B.Sc.

*At Atomic Energy Research Establishment, Harwell, England*—

Principal Research Officer—O. O. Pulley, B.Sc., B.E., Ph.D.
Senior Research Officer—C. D. Boadle, B.M.E.
Senior Research Officer—J. N. Gregory, M.Sc.
Senior Research Officer—R. H. Myers, M.Sc., Ph.D.
Senior Research Officer—G. L. Miles, M.Sc., B.A., Ph.D.
Research Officer—N. A. Faull, B.Sc.
Research Officer—D. F. Sangster, B.Sc.

### 5 DIVISION OF BIOCHEMISTRY AND GENERAL NUTRITION.

(Head-quarters: University of Adelaide.)

Chief—H. R. Marston, F.R.S.
Divisional Secretary—J. Ward Walters.
Principal Research Officer—A. W. Peirce, D.Sc.
Senior Research Officer—E. W. Lines, B.Sc.

Senior Research Officer—D. S. Riceman, M.Sc., B.Agr.Sc.
Senior Research Officer—H. J. Lee, M.Sc.
Senior Research Officer—F. V. Gray, M.Sc.
Senior Research Officer—**Miss M. C. Dawbarn, M.Sc.** (half-time).
Research Officer—G. B. Jones, M.Sc.
Research Officer—I. G. Jarrett, M.Sc.
Research Officer—T. A. Quinlan-Watson, M.Sc.
Research Officer—H. J. Rodda, Ph.D., M.Sc.
Research Officer—Miss S. H. Allen, B.Sc.
Research Officer—Miss P. M. Macbeth, B.Sc.
Research Officer—A. F. Pilgrim, B.Sc.
Research Officer—B. J. Potter, M.Sc.
Research Officer—J. K. Powrie, B.Sc. (Agric.)
Research Officer—R. M. Smith, B.Sc.
Research Officer—R. A. Weller, B.Sc.
Research Officer—R. E. Kuchel, B.Sc.
Senior Technical Officer—D. W. Dewey.
Technical Officer—R. E. Underdown, A.S.A.S.M.
Technical Officer—R. M. Sangster, R.D.A.
Technical Officer—J. O. Wilson (part-time).
Technical Officer—C. E. Sleigh.
Technical Officer—R. F. Trowbridge.
Technical Officer—D. F. Graham.
Technical Officer—V. A. Stephen.
Farm Manager—R. H. Jones, R.D.A.
Librarian—Miss I. Sanders, B.A. (on leave).
Assistant Librarian—Miss P. M. Smith.

### 6. Division of Building Research.

(Head-quarters: Graham-road, Highett, Victoria.)

*Administration—*

Chief—Ian Langlands, M.Mech.E., B.E.E.
Technical Secretary—W. F. Evans, B.Sc.

*Information and Library—*

Senior Research Officer—J. R. Barned, B.Sc.
Research Officer—R. C. McTaggart, B.Sc.
Research Officer (part-time)—Mrs. C. M. Petrie, M.A., Ph.D.
Technical Officer (photography)—E. S. Smith.
Librarian—Miss S. A. Hammill.

*Mechanical and Physical Testing Laboratory—*

Senior Research Officer—P. H. Sulzberger, B.Sc.
Research Officer—R. E. Lewis, B.Sc.
Technical Officer—W. U. S. Falk, F.M.T.C.
Technical Officer—A. Healy, B.Sc.

*Concrete Investigations—*

Research Officer—F. A. Blakey, B.E., Ph.D.
Research Officer—W. H. Taylor, M.C.E.
Technical Officer—E. H. Mattison.

*Masonry Investigations—*

Principal Research Officer—J. S. Hosking, M.Sc., Ph.D.
Senior Research Officer—H. V. Hueber, Dr.Phil.
Research Officer—W. F. Cole, M.Sc., Ph.D.
Research Officer—R. H. Hill, B.Sc., B.Com.
Research Officer—J. A. Ferguson, M.Sc. (abroad).
Technical Officer—A. R. Carthew, B.Sc.
Technical Officer—Miss M. E. Neilson, B.Sc.
Technical Officer—A. E. Holland, A.M.T.C.

*Surfacing Materials Investigations—*

Senior Research Officer—E. H. Waters, M.Sc.
Research Officer—J. M. Hutson, M.A., B.Sc.
Research Officer—J. E. Bright, B.Sc.
Research Officer—Mrs. T. Demediuk, Dr. Phil.
Technical Officer—D. A. Powell, B.Sc.
Technical Officer—I. McLachlan.
Technical Officer—G. H. Price, B.Sc.

*Building Boards, Insulating Materials, and Acoustics—*

Research Officer—R. W. Muncey, B.E.E.
Research Officer—A. F. Nickson, M.Sc.
Research Officer—T. S. Holden, B.Sc.

Technical Officer—A. W. Wilson, Dip.Mech.Eng., Dip.Elec.Eng.
Technical Officer—J. J. Russell.

*Organic Materials Investigations—*

Senior Research Officer—B. M. Holmes, M.Sc.
Research Officer—E. R. Ballantyne, B.Sc.
Research Officer—J. S. Greenland, B.Sc.(App.)
Technical Officer—N. G. Brown, A.M.T.C.
Technical Officer—J. W. Spencer, B.Sc.

*Drawing Office—*

Sectional Draughtsman—G. T. Stephens, Dip.Mech. Eng., Dip.Elec.Eng.
Draughtsman—D. S. C. Smith.

### 7. Coal Research Section.

(Head-quarters: Delhi-road, North Ryde, New South Wales.)

Officer-in-Charge—H. R. Brown, B.Sc.Eng.
Technical Secretary—L. Taylor, B.Sc.(Min.Eng.)
Assistant Librarian—Miss J. M. Hazlitt, B.A.
Senior Research Officer—H. Berry, M.Sc.(Tech.)
Senior Research Officer—T. D. Morgan, B.Sc.
Research Officer—R. H. Jones, B.Sc.
Survey Officer—O. Morris.
Survey Officer—M. S. Burns.
Technical Officer—H. F. A. Hergt, A.M.T.C.
Technical Officer—R. A. Oxenford, B.Sc.
Technical Officer—Miss B. J. Hewitt, B.Sc.

### 8. Commonwealth Research Station (Murray Irrigation Areas).

(Head-quarters: Merbein, Victoria.)

Officer-in-Charge—A. V. Lyon, M.Agr.Sc.
Principal Research Officer—E. C. Orton, B.Sc.
Senior Research Officer—J. G. Baldwin, B.Agr.Sc., B.Sc.
Research Officer—G. V. F. Clewett, B.Sc.
Research Officer—W. J. Webster, B.Sc.
Research Officer—A. J. Antcliff, B.Sc.
Research Officer—M. R. Sauer, B.Agr.Sc.
Research Officer—S. F. Bridley, B.Agr.Sc.
Research Officer—R. C. Woodham, B.Agr.Sc.
Research Officer—D. M. Alexander, B.Sc.
Research Officer—L. R. Finch, B.Sc.
Senior Technical Officer—J. E. Giles.
District Officer (Nyah-Woorinen) — R. C. Polkinghorne (part-time).
District Officer (Wakool)—H. Jackson (part-time).
District Officer (Renmark)—J. V. Seekhamp (part-time).

### 9. Dairy Research Section.

(Head-quarters: Lorimer-street, Fisherman's Bend, Melbourne.)

Officer-in-Charge—G. Loftus Hills, B.Agr.Sc.
Senior Research Officer—E. G. Pont, M.Sc.Agr.
Research Officer—J. Conochie, B.Sc.(Agric.).
Research Officer—A. J. Lawrence, B.Sc.
Research Officer—D. A. Forss, M.Sc.
Research Officer—J. W. Lee, B.Sc.
Research Officer—K. Kumetat, Ph.D.

### 10. Division of Electrotechnology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—F. J. Lehany, M.Sc.
Technical Secretary—R. C. Richardson, B.E.
Senior Research Officer—L. G. Dobbie, M.E.
Senior Research Officer—W. K. Clothier, B.Sc., M.E.
Senior Research Officer—R. J. Meakins, B.Sc., Ph.D.
Senior Research Officer—A. M. Thompson, B.Sc.
Senior Research Officer—R. A. Sack, B.Sc., Ph.D.
Senior Research Officer—B. V. Hamon, B.Sc., B.E.

Research Officer—D. L. Hollway, B.E.E., M.Eng.Sc.
Research Officer—L. Medina, Dipl.Ing.
Research Officer—D. C. Pawsey, B.E.E.
Research Officer—J. S. Dryden, M.Sc.
Research Officer—G. J. A. Cassidy, B.E.E.
Research Officer—H. W. Stokes, B.Ec.
Research Officer—P. G. Walker, B.Sc.
Research Officer—T. M. Palmer, Dipl.F.H.
Research Officer—H. K. Welsh, M.Sc.
Research Officer—D. W. Posener, B.Sc.
Research Officer—Miss J. W. Mulley, A.S.T.C.
Research Officer—J. J. O'Dwyer, B.Sc., B.E. (abroad).
Research Officer—D. L. H. Gibbings, B. E. (abroad).
Senior Technical Officer—L. M. Mandl, Dipl.Ing., A.S.T.C.
Senior Technical Officer—F. C. Brown, A.S.T.C.
Technical Officer—E. G. Filby.
Technical Officer—R. W. Archer, A.S.T.C.
Technical Officer—H. A. Smith, A.S.T.C.
Technical Officer—Miss M. C. Clark, B.Sc., A.S.T.C.
Technical Officer—H. Bairnsfather.
Technical Officer—E. Cowcher, A.S.T.C.
Technical Officer—R. L. Gregory, A.S.T.C.

### 11. Division of Entomology.

(Head-quarters: Canberra, Australian Capital Territory.)

*At Canberra*—
*Administration*—
Chief—A. J. Nicholson, D.Sc.
Technical Secretary—I. F. B. Common, M.A., B.Agr.Sc.
Librarian (half-time)—Miss J. Humphreys, B.A., Dip.Ed.
Senior Clerical Officer (half-time)—K. J. Prowse.
Accountant (half-time)—D. W. Banyard.
Illustrator—L. A. Marshall.
*Biological Control*—
Senior Research Officer—F. Wilson.
Research Officer—E. F. Riek, M.Sc.
Technical Officer—G. R. Wearne.
*Museum*—
Research Officer—T. G. Campbell.
*Taxonomy of Diptera*—
Senior Research Officer—S. J. Paramonov, D.Sc.
*Physiology and Toxicology*—
Senior Research Officer—D. F. Waterhouse, M.Sc., A.A.C.I.
Senior Research Officer—D. Gilmour, M.Sc.
Research Officer—R. H. Hackman, M.Sc., Ph.D.
Research Officer—R. F. Powning, A.S.T.C.
Technical Officer—J. H. Calaby.
Technical Officer—L. G. Webber.
*Insecticide Investigations*—
Research Officer—R. W. Kerr, B.Sc.
*Locust and Pasture Pests*—
Senior Research Officer—K. H. L. Key, D.Sc.
Research Officer—P. B. Carne, B.Agr.Sc.
*Virus Vector Investigations*—
Senior Research Officer—M. F. Day, B.Sc., Ph. D.
Technical Officer—N. E. Grylls, D.D.A.
Technical Officer—Miss A. K. McKinnon, B.Sc.
*Termite Investigations*—
Senior Research Officer—F. J. Gay, B.Sc., D.I.C.
Technical Officer—A. Wetherley.
*Sheep Blowfly Investigations*—
Senior Research Officer—K. R. Norris, M.Sc.
*Cattle Tick Investigations*—
Research Officer—P. R. Wilkinson, M.A.
*Meat Ant Investigations*—
Research Officer—T. Greaves.
*Population Dynamics*—
Chief of Division—A. J. Nicholson, D.Sc.
Technical Officer—A. T. Mills.
Technical Officer—S. Dee.
*At Yeerongpilly, Queensland*—
*Cattle Tick Investigations*—
Senior Research Officer—L. F. Hitchcock, M.Sc.
Research Officer—W. J. Roulston, B.Sc.
Research Officer—G. J. Snowball, B.Sc.
Technical Officer—R. A. J. Meyers, Q.D.A.H., Q.D.D.
Technical Officer—J. T. Wilson, Q.D.A.
Technical Officer—B. F. Healy, Q.D.A.
*In Western Australia*—
*Earth Mite Investigations*—
Research Officer—M. M. H. Wallace, B.Sc. (abroad).
Technical Officer—J. A. Mahon, Dip.D.Sci.
*At Bright, Victoria*—
*St. John's Wort Investigations*—
Senior Research Officer—L. R. Clark, M.Sc.
Research Officer—Mrs. N. Clark, B.Sc.Agr.
Technical Officer—E. R. Pearce, Dip.Agr.
*At Trangie, New South Wales*—
*Locust Investigations*—
Technical Officer—L. J. Chinnick, R.D.A.

### 12. Division of Fisheries.

(Head-quarters: Cronulla, New South Wales.)

*At Cronulla*—
Chief—H. Thompson, M.A., D.Sc.
Technical Secretary—Mrs. L. M. Willings, B.A.
Senior Principal Research Officer—G. W. Rayner, M.Sc.
Senior Research Officer (bacteriologist)— E. J. Ferguson Wood, B.A., M.Sc.
Research Officer (chemist and hydrologist)—D. J. Rochford, B.Sc.
Research Officer (biologist)—I. S. R. Munro, M.Sc.
Research Officer (ichthyologist)—A. M. Rapson, M.Sc.
Research Officer (biologist)—G. S. Grace, B.Sc.
Research Officer (planktologist)—Miss P. Kott, M.Sc. (abroad).
Research Officer (algologist)—A. B. Cribb, B.Sc.
Technical Officer (hydrologist)—H. R. Jitts, B.Sc.
Marine Superintendent—Commander R. H. Thornton.
Senior Technical Officer (laboratory)—A. Proctor.
Gear Officer—A. Temple.
*At Melbourne*—
Research Officer (biologist)—M. Blackburn, M.Sc. (overseas).
Technical Officer (biologist)—P. E. Gartner, B.Sc.
*At Perth*—
Senior Research Officer (officer-in-charge, biologist) —D. L. Serventy, B.Sc., Ph.D.
Research Officer (chemist and hydrologist)—R. S. Spencer, B.Sc.
Research Officer (biologist)—K. Sheard.
Research Officer (biologist)—W. B. Malcolm, B.Sc.
*At Hobart*—
Senior Research Officer (biologist)—A. G. Nicholls, B.Sc., Ph.D.
Research Officer (biologist)—A. M. Olsen, M.Sc.
Technical Officer (biologist)—D. E. Kurth, B.Sc.
*At Dunwich, Queensland*—
Research Officer (biologist)—J. M. Thomson, M.Sc.
*At Thursday Island, Queensland*—
Research Officer (biologist)—J. S. Hynd, B.Sc.

### 13. Flax Research Section.

(Head-quarters: Graham-road, Highett, Victoria.)
Officer-in-Charge—W. L. Greenhill, M.E.
Senior Research Officer—Miss J. F. Couchman, B.Sc.
Senior Research Officer—G. W. Lanigan, M.Sc.
Research Officer—W. Shepherd, B.Sc., B.Ag.Sc.
Technical Officer—D. K. Haslam.
Technical Officer—M. Tisdall.
Technical Officer—W. G. Lewis, B.Sc., B.A.

### 14. Division of Food Preservation and Transport.

(Head-quarters: State Abattoir, Homebush Bay; Postal address: Private Bag, Homebush P.O., New South Wales.)

*Administration and General*—
Chief—J. R. Vickery, M.Sc., Ph.D.
Technical Secretary—R. B. Withers, M.Sc., Dip.Ed.
Librarian—Miss B. Johnston, B.Sc.
Assistant Librarian—Miss J. Hay.
Maintenance Engineer—T. L. Swan.

*Physics Section*—
Principal Research Officer—E. W. Hicks, B.A., B.Sc.
Research Officer—M. C. Taylor, M.Sc.
Research Officer—G. M. Rostos, Dipl.Ing.
Technical Officer—M. B. Smith, A.S.A.S.M.
Technical Officer—J. Mellor.

*Microbiology Section*—
Principal Research Officer—W. J. Scott, B.Agr.Sc.
Research Officer—M. R. J. Salton, B.Sc.Agr. (on leave).
Research Officer—W. G. Murrell, B.Sc.Agr. (on leave).
Technical Officer—P. R. Maguire.
Technical Officer—D. F. Ohye, D.I.C.

*General Chemistry Section*—
Senior Research Officer—F. E. Huelin, B.Sc., Ph.D.
Research Officer—H. A. McKenzie, M.Sc.
Research Officer—Mrs. A. R. Thompson, M.Sc.
Technical Officer—R. A. Gallop, A.S.T.C.

*Fruit and Vegetable Storage Section*—
Principal Research Officer—R. N. Robertson, B.Sc., Ph.D.
Senior Research Officer—E. G. Hall, B.Sc.Agr.
Research Officer—J. F. Turner, M.Sc. (on leave).
Research Officer—Miss M. Wilkins, M.Sc. (on leave).
Technical Officer—Miss L. Grauaug, B.Sc.

*Canning and Fruit Products Section*—
Principal Research Officer—L. J. Lynch, B.Agr.Sc.
Senior Research Officer—J. F. Kefford, M.Sc.
Research Officer—R. S. Mitchell, M.Sc.Agr.
Research Officer—B. V. Chandler, B.Sc.
Research Officer—E. G. Davis, B.Sc.
Research Officer—P. W. Board, B.Sc.
Technical Officer—D. Moyes, B.Sc.Agr.

*Dried Foods Section*—
Senior Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil.
Research Officer—D. McG. McBean, B.Sc.
Research Officer—J. Shipton, B.Sc.Agr.
Research Officer—W. J. Herzberg, B.Sc.
Technical Officer—F. Fitzpatrick, A.S.T.C.

*Fish Investigations*—
Senior Research Officer—W. A. Empey, B.V.Sc.
Research Officer—J. B. Adams, B.Sc.
Technical Officer—R. Allan.
Technical Officer—K. W. Anderson, A.M.T.C.

*Meat and Egg Investigations*—
Senior Research Officer—A. R. Riddle, A.B., M.S.
Technical Officer—F. S. Shenstone, A.S.T.C.

*Freezing of Fruit and Vegetables*—
Research Officer—I. J. Tinsley, B.Sc.

*At University of Sydney*—
Research Officer (fruit storage)—H. S. McKee, B.A., D.Phil.
Research Officer (fruit storage)—Miss J. Fraser, B.Sc.
Technical Officer (fruit storage)—Miss G. Bruck, B.Sc.

*At Auburn, New South Wales*—
Research Officer (meat dehydration)—A. R. Prater, B.Sc.Agr.

*At University of Melbourne*—
Research Officer (microbiology)—B. T. Overell, M.Sc.

*At Brisbane*—
*Meat Investigations*—
Officer-in-Charge—A. Howard, M.Sc.
Senior Research Officer—G. Kaess, Dr. Ing.
Research Officer—A. D. Brown, B.Sc.
Technical Officer—H. A. McDonald, D.I.C.
Technical Officer—N. T. Russell, D.I.C.

*At Australia House, London*—
Senior Research Officer—N. E. Holmes, B.E.E., M.Mech.E.

### 15. Division of Forest Products.

(Head-quarters: 69 Yarra Bank-road, South Melbourne.)

*Administration*—
Chief—S. A. Clarke, B.E.
Assistant to Chief—C. S. Elliott, B.Sc.
Assistant to Chief—H. E. Dadswell, D.Sc.
Librarian—Miss M. I. Hulme.
Assistant to Librarian—Miss A. Forbes.
Senior Technical Officer—L. Santer, Dip.Eng.

*Wood Structure Section*—
Senior Principal Research Officer-in-Charge—H. E. Dadswell, D.Sc.
Senior Research Officer—Miss M. M. Chattaway, M.A., B.Sc., D.Phil.
Senior Research Officer—H. D. Ingle, B.For.Sc.
Research Officer—G. L. Amos, M.Sc.
Research Officer—I. J. W. Bisset, B.Sc.
Research Officer—A. B. Wardrop, M.Sc., Ph.D.
Technical Officer—W. McKenzie, B.Sc.
Technical Officer—K. M. Chapman, B.Sc.

*Photography*—
Technical Officer—Miss Audrey M. Lightfoot.
Technical Officer—W. G. Hastie.

*Wood Chemistry Section*—
Senior Principal Research Officer-in-Charge—W. E. Cohen, D.Sc.
Senior Research Officer—D. E. Bland, M.Sc.
Research Officer—Miss C. M. Emery, B.Sc.
Research Officer—D. H. Foster, M.Sc.
Research Officer—A. von Koeppen, Dr. Ing.
Research Officer—C. M. Stewart, B.Sc.
Research Officer—A. J. Watson, A.M.T.C.
Technical Officer—A. G. Charles.
Technical Officer—W. E. Hillis, B.Sc., A.G. Inst. Tech.
Technical Officer—L. T. Poole, A.Swin.T.C.
Technical Officer—Miss G. M. Schwerin, B.S.

*Timber Physics Section*—
Senior Research Officer-in-Charge—R. S. T. Kingston, B.Sc., B.E.
Research Officer—L. N. Clarke, B.Eng.Sc.
Research Officer—Miss K. E. Kelsey, B.Sc.
Technical Officer—A. Ack Hing, A.S.M.B.
Technical Officer—L. D. Armstrong.

Technical Officer—N. C. Edwards, A.S.M.B.
Technical Officer—J. W. P. Nicholls, B.Sc.
Technical Officer—I. G. Scott, B.Sc., F.M.T.C.

*Timber Mechanics Section—*

Principal Research Officer-in-Charge—K. L. Cooper, M.A., B.Sc.
Senior Research Officer—J. D. Boyd, M.C.E.
Research Officer—N. H. Kloot, B.Sc.
Research Officer—R. G. Pearson, B.C.E.
Technical Officer—J. J. Mack.

*Timber Seasoning Section—*

Principal Research Officer-in-Charge—G. W. Wright, M.E.
Research Officer—C. E. Dixon, M.Sc.
Research Officer—E. L. Ellwood, M.Sc.(For.).
Research Officer—J. W. Gottstein, B.Sc.
Senior Technical Officer—F. A. Dale, Dip.Mech.Eng.
Technical Officer—L. J. Brennan.
Technical Officer—G. S. Campbell.
Technical Officer—H. D. Roberts.

*Timber Preservation Section—*

Senior Research Officer-in-Charge—N. Tamblyn, M.Sc.(Agric.).
Research Officer—G. W. Tack, B.Agr.Sc. (Acting-in-Charge).
Research Officer—G. N. Christensen, B.Sc.
Research Officer—E. W. B. Da Costa, M.Agr.Sc.
Research Officer—R. B. Jackson, M.Sc.
Technical Officer—J. Beesley, B.Sc.(For.), Dip.For.
Technical Officer—R. E. Kneale, D.A.C.
Technical Officer—Miss N. Robinson.
Technical Officer—A. Rosel.
Technical Officer—N. E. M. Walters, B.Sc.

*Veneer and Gluing Section—*

Senior Research Officer-in-Charge—A. Gordon, B.Sc.
Research Officer—H. G. Higgins, B.Sc.
Research Officer—K. F. Plomley, B.Sc.Agric.
Technical Officer—Miss J. U. Barrie.
Technical Officer—D. M. Cullity, B.Sc.
Technical Officer—J. F. Hayes, B.Sc.
Technical Officer—K. Hirst.

*Utilization Section—*

Principal Research Officer-in-Charge — R. F. Turnbull, B.E.
Research Officer—C. H. Hebblethwaite, Dip.For.
Technical Officer—S. J. Colwell, Dip.Mech.Eng.
Technical Officer—R. L. Cowling, Dip.Mech.Eng., Dip.E.E.

*Maintenance Section—*

Senior Technical Officer—S. G. McNeil.

### 16. DIVISION OF INDUSTRIAL CHEMISTRY.

(Head-quarters: Lorimer-street, Fishermen's Bend, Melbourne; Postal address: Box 4331, G.P.O., Melbourne.)

*Administration—*

Chief—I. W. Wark, D.Sc., Ph.D.
Divisional Secretary—L. Lewis, B.Met.E.
Assistant Secretary—A. E. Scott, M.Sc.

*Minerals Utilization Section—*

Senior Principal Research Officer—R. G. Thomas, B.Sc.
Senior Research Officer—A. Walkley, B.A., D.Sc., Ph.D.
Senior Research Officer—A. W. Wylie, M.Sc., Ph.D.
Research Officer—P. Dixon, M.Sc.
Research Officer—F. K. McTaggart, M.Sc.
Research Officer—T. R. Scott, D.Sc., B.Ed.
Research Officer—F. R. Hartley, M.Sc.
Research Officer—A. D. Wadsley, M.Sc.
Research Officer—R. C. Croft, M.Sc.
Research Officer—I. C. Kraitzer.
Research Officer—E. S. Pilkington, A.S.T.C.
Research Officer—I. E. Newnham, M.Sc.
Research Officer—J. D. Hayton, B.Sc. (at S.A. School of Mines, Adelaide).
Research Officer—R. C. Vickery, M.Sc., Ph.D.
Technical Officer—H. R. Skewes, A.A.C.I.

*Cement and Ceramics Section—*

Senior Principal Research Officer—A. R. Alderman, D.Sc., Ph.D.
Senior Research Officer—W. O. Williamson, B.Sc., Ph.D.
Research Officer—A. J. Gaskin, M.Sc. (part-time).
Research Officer—H. E. Vivian, B.Sc.Agr.
Research Officer—S. M. Brisbane, B.A., A.M.T.C.
Research Officer—E. R. Segnit, M.Sc. (abroad).
Research Officer—C. E. S. Davis, B.Sc.
Research Officer—H. R. Sampson, M.Sc.
Research Officer—K. M. Alexander, M.Sc., Ph.D.
Research Officer—G. M. Bruere, M.Sc.
Research Officer—H. Ellerton (at Bonython Research Laboratory, S.A. School of Mines, Adelaide).
Senior Technical Officer—J. Coutts, A.M.T.C.
Technical Officer—Miss B. C. Terrell, B.Sc.
Technical Officer—J. H. Weymouth, B.Sc.
Technical Officer—J. D. Wolfe.

*Foundry Sands Section—*

Research Officer—H. A. Stephens, B.Sc.
Technical Officer—A. N. Waterworth, A.H.T.C.

*Physical Chemistry Section—*

Principal Research Officer—K. L. Sutherland, D.Sc., Ph.D.
Research Officer—W. E. Ewers, M.Sc.
Research Officer—Miss A. McV. Lowen, B.Sc., Ph.D.
Research Officer—W. W. Mansfield, B.Sc.
Technical Officer—L. F. Evans, D.S.M.B.

*Chemical Physics Section—*

Senior Principal Research Officer—A. L. G. Rees, D.Sc., Ph.D.
Senior Research Officer—A. Walsh, M.Sc.Tech.
Senior Research Officer—E. H. Mercer, B.Sc., Ph.D.
Senior Research Officer—J. L. Farrant, M.Sc.
Senior Research Officer—A. McL. Mathieson, B.Sc., Ph.D.
Research Officer—D. A. Davies, B.Sc.
Research Officer—J. M. Cowley, M.Sc., Ph.D.
Research Officer—J. D. Morrison, M.Sc., Ph.D.
Research Officer—J. B. Willis, M.Sc., Ph.D.
Research Officer—A. F. Moodie, B.Sc.
Research Officer—C. Billington, B.A.
Research Officer—B. Dawson, M.Sc., Ph.D.
Research Officer—J. P. Shelton, M.Sc., A.B.S.M.
Research Officer—A. J. Hodge, B.Sc. (abroad).
Research Officer—J. V. Sullivan, M.Sc.
Research Officer—J. Fridrichsons, M.Sc.
Research Officer—T. C. Somers, M.Sc.
Research Officer—J. C. Riviere, M.Sc.
Senior Technical Officer—W. G. Jones.
Technical Officer—R. J. Beckett, B.Sc.
Technical Officer—S. E. Powell.
Technical Officer—G. F. H. Box.
Technical Officer—F. B. Williams.
Draughtsman—N. McVilly.

*Organic Section—*

Senior Principal Research Officer—H. H. Hatt, D.Sc., Ph.D.
Senior Research Officer — J. S. Fitzgerald, M.Sc., Ph.D.
Senior Research Officer—J. R. Price, M.Sc., D.Phil.
Research Officer—M. E. Winfield, M.Sc., Ph.D.
Research Officer—K. E. Murray, B.Sc.
Research Officer—R. G. Curtis, M.Sc., D.I.C.
Research Officer—R. J. L. Martin, M.Sc., Ph.D.
Research Officer—N. C. Hancox, M.Sc.

Research Officer—L. K. Dalton, A.S.T.C.
Research Officer—R. B. Bradbury, B.Sc.Agr., D.B.S.M. (at University of Western Australia).
Research Officer—W. D. Crow, M.Sc. (abroad).
Research Officer—P. H. A. Strasser, M.Sc.
Research Officer—L. J. Drummond, M.Sc.
Research Officer—H. Duewell, D.Sc., Ph.D.
Research Officer—C. S. Barnes, B.Sc.
Research Officer—N. V. Riggs, B.Sc., Ph.D.
Technical Officer—R. Schoenfeld, B.Sc.
Technical Officer—Miss E. E. Rutherford, B.Sc.

*Chemical Engineering Section—*

Principal Research Officer—D. R. Zeidler, M.Sc.
Research Officer—I. Brown, B.Sc.
Research Officer—R. W. Urie, B.Sc., S.M.
Research Officer—J. F. Pearse, B.Sc., Ph.D., D.I.C. (at Chemical Engineering Department, University of Sydney).
Research Officer—B. W. Wilson, M.Sc.
Research Officer—D. E. Weiss, B.Sc.
Research Officer—M. L. Newman, B.Sc.App. (at Chemical Engineering Department, University of Sydney).
Research Officer—K. R. Hall, B.Sc.
Research Officer—O. G. Ingles, M.Sc.
Research Officer—S. D. Hamann, M.Sc., Ph.D. (at Chemical Engineering Department, University of Sydney).
Research Officer—H. G. David, B.Sc. (at Chemical Engineering Department, University of Sydney).
Research Officer—J. A. Barker, B.A., B.Sc.
Senior Technical Officer—L. R. Bull, Dip.Mech.Eng.
Technical Officer—J. L. Clay, A.M.T.C.
Technical Officer—J. B. Ross, B.Sc., A.M.T.C.
Technical Officer—D. H. Trethewey, A.M.T.C. (abroad).
Technical Officer—A. Ewald, B.Sc.
Technical Officer—E. F. Symons, A.M.T.C.
Technical Officer—E. M. Jenkins, A.M.T.C.
Technical Officer—M. Linton, B.Sc.
Technical Officer—K. W. Foley, B.Sc.
Technical Officer—M. Ross, Ing.
Technical Officer—L. C. Bennett, B.Sc.
Technical Officer—R. W. Lennie, A.M.T.C.
Sectional Draughtsman—C. Simpson.
Draughtsman—J. Hession.

*At University of Western Australia—*

*Alunite Investigations—*

Research Officer—D. F. A. Koch, B.Sc.

*Photography—*

Technical Officer—F. D. Lugton.

*Library—*

Librarian—Miss B. M. Brown, B.Sc.

### 17. Irrigation Research Station (Murrumbidgee Irrigation Areas).

(Head-quarters: Griffith, New South Wales.)

Officer-in-Charge—E. S. West, B.Sc., M.S.
Senior Research Officer (plant physiology)—R. F. Williams, M.Sc.
Research Officer (irrigation)—O. Perkman, B.Sc.Agr.
Research Officer (drainage)—V. J. Wagner, B.Sc.Agr.
Research Officer (vegetable agronomy)—K. Spencer, B.Sc.Agr.
Research Officer (weeds)—L. F. Myers, B.Sc.Agr.
Research Officer (horticulture)—H. J. Frith, B.Sc. Agr.
Research Officer (plant physiology)—C. T. Gates, B.Sc.Agr.
Research Officer (soil physics)—E. L. Greacen, B.Sc.Agr., Ph.D.
Senior Technical Officer (orchard superintendent)—B. H. Martin, H.D.A.
Technical Officer (photography)—A. N. Huon.
Technical Officer (chemistry)—Miss J. Connor, B.Sc.
Technical Officer (vegetable agronomy)—A. Wlasow, Ch.(D).
Technical Officer (chemistry)—Dr. G. Sosnovsky.
Librarian—Miss M. Russell.

*Seconded to New South Wales Department of Agriculture—*

Senior Research Officer—R. R. Pennefather, B.Agr.Sc.
Senior Research Officer—D. V. Walters, M.Agr.Sc.
Research Officer—A. F. Gurnett-Smith, B.Agr.Sc., Q.D.D.
Research Officer—Mrs. J. Tully, B.Sc., Ph.D.

### 18. Section of Mathematical Instruments.

(Head-quarters: University of Sydney.)

Officer-in-Charge—Professor D. M. Myers, B.Sc., D.Sc.Eng.
Senior Research Officer—W. R. Blunden, B.Sc., B.E.
Technical Officer—R. J. Keith, A.S.T.C.
Seconded from Department of Post-war Reconstruction—H. Billing, D.Nat.Phil.

### 19. Section of Mathematical Statistics.

(Head-quarters: University of Adelaide.)

*At Sectional Head-quarters, Adelaide—*

Officer-in-Charge—E. A. Cornish, M.Sc., B.Agr.Sc.
Research Officer—A. T. James, M.Sc.
Research Officer—N. S. Stenhouse, B.Sc.
Research Officer—G. N. Wilkinson, B.Sc.
Sectional Secretary—Miss E. M. G. Goodale.

*At Division of Animal Health and Production, Sydney—*

Senior Research Officer—Miss H. A. Newton Turner, B.Arch.
Research Officer—Miss E. F. Foster, B.Sc.
Research Officer—Miss M. C. McKevett, B.Sc.

*At Division of Food Preservation and Transport, Homebush—*

Research Officer—G. G. Coote, B.A., B.Sc.

*At Division of Forest Products, Melbourne—*

Senior Research Officer—E. J. Williams, B.Com. (abroad).
Research Officer—R. T. Leslie, B.A., B.Sc.
Research Officer—R. Birtwistle, B.Sc.

*At Division of Plant Industry, Canberra—*

Senior Research Officer—G. A. McIntyre, B.Sc., Dip.Ed.
Research Officer—Miss N. B. Hemingway, B.Sc.

### 20. Section of Meteorological Physics.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-Charge—C. H. B. Priestley, M.A.
Principal Research Officer—W. C. Swinbank, B.Sc.
Senior Research Officer—E. L. Deacon, B.Sc.
Senior Research Officer—R. W. James, M.Sc.
Research Officer—I. C. McIlroy, B.Sc.
Research Officer—R. M. Fry, B.Sc.
Research Officer—E. K. Webb, B.A., B.Sc.
Senior Technical Officer—R. J. Taylor, B.Sc.
Technical Officer—I. S. Groodin, Dip.Mat.
Technical Officer—D. E. Angus, B.Sc.
Technical Officer—Mrs. R. I. Lee.

### 21. Division of Metrology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—N. A. Esserman, B.Sc., F.Inst.P., A.M.I.E. (Aust.).
Technical Secretary—N. H. Winters, B. E., A.M.I.E. (Aust.).

Senior Research Officer—P. M. Gilet, B.Sc., B.E., F.Inst.P., A.M.I.E. (Aust.).
Senior Research Officer—H. J. Ritter, Dr.rer.nat.-math.
Senior Research Officer—G. A. Bell, B.Sc., A.Inst.P.
Research Officer—C. F. Bruce, M.Sc., A.Inst.P.
Research Officer—H. A. Ross, A.S.T.C., A.M.I.E. (Aust.).
Research Officer—J. A. Macinante, B.E., A.S.T.C., Jr.I.E. (Aust.).
Research Officer—R. H. Furniss, A.S.T.C., A.M.I.E. (Aust.).
Research Officer—W. A. F. Cuninghame, B.E.
Research Officer—Miss M. C. Dive, B.Sc.
Research Officer—Miss M. G. I. Pearce, M.Sc.
Research Officer—Miss P. M. Yelland.
Research Officer—R. J. Ellis, B.E., Jr.I.E. (Aust.).
Research Officer—J. Waldersee, B.Sc.
Research Officer—Miss M. M. Douglas, B.Sc.
Research Officer—N. J. C. Peres, B.Sc.
Technical Officer—E. J. Thwaite, B.Sc.
Technical Officer—J. C. Kelly, B.Sc.
Technical Officer—G. W. Gore, A.S.T.C.
Technical Officer—W. Dollar, A.S.T.C.
Technical Officer—I. J. Somervaille, A.S.T.C.
Technical Officer—S. A. Dunk, A.S.T.C.
Technical Officer—J. W. Bell.
Technical Officer—D. H. Fox.
Technical Officer—O. Pain.

### 22. MINERAGRAPHIC INVESTIGATIONS.

(Head-quarters: University of Melbourne.)

Senior Principal Research Officer—F. L. Stillwell, D.Sc.
Principal Research Officer—A. B. Edwards, D.Sc., Ph.D.
Research Officer—G. Baker, M.Sc.
Technical Officer—G. C. Carlos.

### 23. NATIONAL STANDARDS LABORATORY.

(The services shown hereunder are common to the Divisions of Metrology, Electrotechnology, and Physics, housed in the Laboratory.)

*Clerical*—
Chief Clerk—W. J. Gillespie, A.F.I.A., A.C.I.S.

*Drawing Office*—
Chief Draughtsman—C. M. Williamson.

*Library*—
Librarian—Miss M. Barnard, B.A.
Librarian—Miss M. McKechnie, B.A.
Librarian—Miss J. M. Cook.
Assistant Librarian—Mrs. B. Walker.

*Workshops*—
Engineer-in-charge—J. Hanna.

### 24. OENOLOGICAL RESEARCH.

(Head-quarters: Waite Agricultural Research Institute, Adelaide.)

Senior Research Officer—J. C. M. Fornachon, M.Sc., B.Ag.Sc.
Research Officer—B. C. Rankine, B.Sc.

### 25. ORE-DRESSING INVESTIGATIONS.

*At University of Melbourne*—
Officer-in-Charge—Associate-Professor H. H. Dunkin, B.Met.E. (part-time).
Senior Research Officer—K. S. Blaskett, B.E.
Research Officer—S. B. Hudson, B.Sc.
Technical Officer—F. D. Drews.
Technical Officer—R. R. Lever.

*At School of Mines, Kalgoorlie, Western Australia*—
Officer-in-Charge—R. A. Hobson, B.Sc. (part-time).

### 26. SECTION OF PHYSICAL METALLURGY.

(Head-quarters: University of Melbourne.)

Officer-in-Charge (honorary)—Professor J. Neill Greenwood, D.Sc., M.Met.E.
Senior Research Officer—H. W. Worner, M.Sc.
Senior Research Officer—A. D. McQuillan, B.Sc.
Research Officer—R. C. Gifkins, B.Sc.
Research Officer—A. E. Jenkins, M.Eng.Sc.
Technical Officer—J. A. Corbett.

### 27. DIVISION OF PHYSICS.

(Head-quarters: National Standards Laboratory at University of Sydney.)

*Administration*—
Chief—Dr. G. H. Briggs, D.Sc., Ph.D.
Technical Secretary—D. S. Woodward.

*Heat*—
Senior Research Officer—A. F. A. Harper, M.Sc.
Research Officer—W. R. G. Kemp, B.Sc.
Research Officer—W. A. Caw, B.Sc.
Research Officer—Miss R. Scott, B.Sc.
Research Officer—N. H. Westwood, B.Sc.
Research Officer—A. J. Mortlock, B.Sc.
Research Officer—G. F. Cawsey, B.Sc.
Technical Officer—J. K. Braithwaite, A.M.T.C.
Technical Officer—J. W. W. Smyth.
Technical Officer—B. J. Rigby, A.S.T.C.

*Light*—
Senior Research Officer—R. G. Giovanelli, D.Sc.
Research Officer—W. H. Steel, B.A., B.Sc.
Research Officer—J. W. Pearce, B.Sc.
Research Officer—K. A. D. Wright, B.Sc.
Research Officer—M. Kossenberg, Ph.D.
Research Officer—R. J. LeMesurier, B.Sc.
Research Officer—G. H. Godfrey, M.A., B.Sc. (part-time).
Technical Officer—V. R. Schaefer.
Technical Officer—W. J. Brown, A.S.T.C.

*Solar Physics*—
Senior Research Officer—R. G. Giovanelli, D.Sc.
Research Officer—J. T. Jefferies, B.Sc.
Research Officer—J. S. Gubbay, B.Sc.

*Wool Research*—
Research Officer—Mrs. K. R. Makinson, B.A.
Technical Officer—Miss J. Griffith, A.S.T.C.

*Electrical Standards*—
Senior Research Officer—A. F. A. Harper, M.Sc.
Research Officer—Miss R. Scott, B.Sc.
Technical Officer—B. J. Rigby, A.S.T.C.

*Electronics*—
Research Officer—A. F. Young, M.Sc.

*Technical Services*—
Technical Officer—J. E. Thompson.

*Officer Abroad*—
Research Officer—R. G. Wylie, M.Sc.

### 28. DIVISION OF PLANT INDUSTRY.

(Head-quarters: Canberra, A.C.T.)

*At Canberra*—
*Administration*—
Chief—B. T. Dickson, B.A., Ph.D.
Assistant Chief—J. G. Davies, B.Sc., Ph.D.
Technical Officer (photographer)—J. B. Pomeroy.
Librarian (half-time)—Miss J. Humphreys, B.A., Dip.Ed.
Assistant Librarian (half-time)—Miss M. Campbell-Smith.
Senior Clerical Officer (half-time)—K. J. Prowse.
Accountant (half-time)—D. W. Banyard.

*Disease Control Studies—*

Principal Research Officer—H. R. Angell, O.B.E., Ph.D.

*Microbiology—*

Senior Research Officer—D. O. Norris, D.Sc. (Agric.)
Senior Research Officer—W. V. Ludbrook, M. S., B.Agr.Sc., Ph.D.
Research Officer—J. H. E. Mackay, B.Sc.Agr.
Research Officer—Miss M. Mills, B.Sc.
Research Officer—Miss K. Helms, B.Sc.
Technical Officer—J. Brockwell, D.D.A.
Technical Officer—N. S. Walker, Dip.Agr.

*Plant Introduction—*

Principal Research Officer—W. Hartley, B.A., Dip.Agr.
Research Officer—C. A. Neal-Smith, B.Agr.Sc., R.D.A.
Technical Officer—R. Seton.

*Horticultural Investigations—*

Principal Research Officer—C. Barnard, D.Sc.

*Medicinal and Drug Plant Investigations—*

Senior Research Officer—K. L. Hills, M.Agr.Sc.
Research Officer—W. Bottomley, B.Sc.
Technical Officer—D. R. Meyer.

*Plant Physiology—*

Senior Research Officer—R. F. Williams, M.Sc. (seconded to Griffith).
Research Officer—J. Calvert, D.Sc.

*Herbarium—*

Research Officer—Miss N. T. Burbidge, M.Sc.

*Agrostology—*

Senior Principal Research Officer—J. G. Davies, B.Sc., Ph.D.
Principal Research Officer—C. M. Donald, M.Agr.Sc.
Research Officer—E. F. Biddiscombe, B.Sc. (Agric.).
Technical Officer—J. Deans.
Technical Officer—L. Lazarides, Q.D.A.
Technical Officer—V. H. Southwell, Dip.Eng.
Technical Officer—A. Axelsen, Q.D.A.H.

*Agrostology, Pasture Ecology—*

Research Officer—C. W. E. Moore, B.Agr.Sc.

*Agrostology, Weeds Ecology—*

Senior Research Officer—R. M. Moore, B.Sc.Agr.
Technical Officer—R. T. Milligan, Dip.Agr.D.
Technical Officer—J. A. Robertson, Q.D.D.M.
Technical Officer—C. S. McKay, Dip.Agr.D.

*Agrostology, Mineral Deficiency Studies—*

Senior Research Officer—A. J. Anderson, B.Sc. (Agric.).
Research Officer—K. D. McLachlan, B.Sc.Agr., B.Comm.
Research Officer—D. Spencer, B.Sc.
Technical Officer—D. Moye, H.D.A.
Technical Officer—R. G. Fawcett, R.D.A.

*Agrostology, Pasture Ecology—*

Senior Research Officer—C. G. Greenham, M.Sc.
Research Officer—P. Goldacre, B.Sc.
Technical Officer—C. V. de Plater, A.I.M.R.E.

*Agrostology, Pasture Chemistry—*

Senior Research Officer—C. H. Williams, M.Sc.
Research Officer—A. Steinbergs.
Research Officer (spectrography)—D. J. David, B.Sc.
Technical Officer—F. K. Mayer, Q.D.A.

*Tobacco Investigations—*

Principal Research Officer—A. V. Hill, M.Agr.Sc.
Research Officer—R. Johanson, M.Sc.
Technical Officer—M. Mandryk.

*Vegetable Investigations—*

Senior Research Officer—E. M. Hutton, M.Sc., B.Agr.Sc.
Research Officer—D. C. Wark, M.Agr.Sc.
Research Officer—R. D. Brock, B.Agr.Sc.
Technical Officer—A. R. Peak, H.D.A.
Technical Officer—R. R. Rochford.
Technical Officer—J. W. Peak.
Technical Officer—J. D. Williams, D.D.A.

*Dickson Experiment Station, Canberra, Australian Capital Territory—*

Senior Research Officer (agrostology)—W. D. Andrew, M.Agr.Sc.
Research Officer (agrostology)—W. M. Willoughby, B.Sc.Agr.
Manager—L. Sharp, Dip.Agr.D.
Technical Officer—J. A. Redpath.

*At Queensland University, Brisbane, Queensland—*

Senior Research Officer (agrostology)—T. B. Paltridge, B.Sc.
Senior Research Officer (plant introduction)—J. F. Miles, B.Agr.Sc.
Research Officer (pasture chemistry)—E. H. Kipps, B.Sc.
Research Officer (native plants investigations)—L. J. Webb, M.Sc.
Librarian—Miss B. Baird.

*At Cooper Laboratory, Queensland Agricultural High School and College, Lawes—*

Research Officer (agrostology)—N. H. Shaw, B.Agr.Sc.
Research Officer (plant introduction)—S. G. Gray, B.Sc.Agr.
Research Officer (agrostology)—W. J. Bisset, B.Agr.Sc.
Research Officer (agrostology)—Miss H. Barford, B.Sc.
Technical Officer (plant introduction)—J. Conroy, Q.D.A.
Technical Officer (agrostology)—R. Milford, Q.D.A.
Technical Officer (agrostology)—G. J. Downing, Q.D.A.H.
Technical Officer (agrostology)—T. W. Elich, Dip.Col.Ag.(Holland).
Technical Officer (agrostology)—W. H. J. Pieters, Dip.Col.Ag.(Holland).
Technical Officer (agrostology)—M. J. Hibberd, Q.D.A.H.
Technical Officer (agrostology)—H. Kiers, Dip.Col.Ag.(Holland).
Technical Officer (agrostology)—G. A. Taylor.

*At Gilruth Plains, Queensland—*

Technical Officer (agrostology)—K. C. Baker, Q.D.A.

*At Stanthorpe, Queensland—*

Senior Research Officer (horticultural investigations)—L. A. Thomas, M.Sc.
Research Officer (horticultural investigations)—R. C. Colbran, B.Agr.Sc.

*At Regional Pastoral Laboratory, Deniliquin, New South Wales—*

Senior Research Officer (agrostology)—R. W. Prunster, B.Sc. (Agric.).
Senior Research Officer (agrostology)—A. L. Tisdall, M.Agr.Sc.
Research Officer (agrostology)—N. Sinicins.
Research Officer (agrostology)—O. B. Williams, B.Agr.Sc.
Research Officer (agrostology)—K. P. J. Barley, B.Agr.Sc.
Technical Officer (agrostology)—K. R. Brown, Dip.Agr.D.

Technical Officer (agrostology)—J. W. Birch.
Technical Officer (agrostology)—F. Arndt, Q.D.A.
Clerical Officer—S. J. Cossar.

*At Falkiner Memorial Field Station, Deniliquin, New South Wales*—

Station Manager—G. A. Vasey.

*At the University of Western Australia, Perth, Western Australia*—

Senior Research Officer (agrostology) — R. C. Rossiter, B.Sc.(Agric.).
Research Officer (plant introduction)—E. T. Bailey, B.Sc.
Technical Officer (agrostology) — R. J. Pack, Q.D.A.
Technical Officer (plant introduction) — N. B. Gayfer, Dip.Agr.D.
Technical Officer (agrostology) — J. Beresford, Dip.Agr.D.

*At Kojonup, Western Australia*—

Station Manager—J. Tudor.
Technical Officer—P. I. Dival, Dip.Agr.(Muresk).

*At Regional Pastoral Laboratory, Armidale, New South Wales*—

Senior Research Officer (agrostology) — R. Roe. B.Sc.(Agric.).
Research Officer (agrostology) — E. J. Hilder, B.Sc.(Agric.).
Research Officer (agrostology)—P. Baxter.
Technical Officer (agrostology)—P. B. Oelrichs.

*At Hobart, Tasmania*—

Senior Research Officer (horticultural investigations)—D. Martin, B.Sc.

*At State Experiment Farm, Trangie, New South Wales*—

Technical Officer (agrostology)—R. J. Hutchings, Dip.Agr.D.

*At Waite Agricultural Research Institute, Adelaide, South Australia*—

Principal Research Officer (physiology)—L. A. T. Ballard, Ph.D., M.Ag.Sc.

*At Ayr, Queensland*—

Research Officer (tobacco) — W. J. Lovett, B.Agr.Sc.
Research Officer (tobacco) — T. G. Haney, B.Sc.Agr.
Technical Officer (tobacco)—D. W. L. Simmons, D.D.A.
Technical Officer (tobacco) — J. D. Fitzsimon, Q.D.A., Q.D.H.

*At Griffith, New South Wales*—

Research Officer (weeds investigations)—L. F. Myers, B.Agr.Sc.

*Land Research and Regional Survey*—

*Head-quarters at Canberra, Australian Capital Territory*—

Principal Research Officer—C. S. Christian, B.Sc.Agr., M.S.
Research Officer—J. P. F. Hennelly, B.Sc.

*At Ayr, North Queensland*—

Research Officer—F. H. Kleinschmidt, B.Sc.Agr.

*At Kimberley Research Station, Western Australia*—

Research Officer—L. C. Lee, B.Agr.Sc.
Technical Officer—E. C. B. Langfield.

*Katherine Experiment Station, Northern Territory*—

Research Officer—W. Arndt, B.Agr.Sc.
Technical Officer—L. J. Phillips, Q.D.D.M.

*Regional Survey, Canberra, Australian Capital Territory*—

Research Officer—G. A. Stewart, B.Agr.Sc.
Research Officer—R. A. Perry, B.Sc.
Technical Officer—M. Lazarides, Q.D.A.

### 29. Radio Research Board.

(Head-quarters: Electrical Engineering Department, University of Sydney.)

*At Canberra*—

Senior Principal Research Officer—D. F. Martyn, D.Sc., Ph.D., A.R.C.Sc., F.R.S.
Technical Officer—R. O. Errey.

*At Sydney*—

Principal Research Officer—G. H. Munro, M.Sc.
Senior Research Officer—W. L. Price, B.Sc. (part-time).
Research Officer—J. A. Harvey, B.Sc.
Research Officer—L. Heisler, B.Sc.
Research Officer—C. B. Kirkpatrick, M.Sc. (part-time).
Technical Officer—Miss B. Hardwick, B.A.
Technical Officer—P. H. Hirschl, A.S.T.C.

### 30. Division of Radiophysics.

(Head-quarters: University of Sydney.)

Chief—E. G. Bowen, O.B.E., M.Sc., Ph.D.
Technical Secretary—A. J. Higgs, B.Sc.

*Research*—

Senior Principal Research Officer—J. L. Pawsey, M.Sc., Ph.D.

*Radio Astronomy*—

Principal Research Officer—J. H. Piddington, M.Sc., B.E., Ph.D.
Senior Research Officer—W. N. Christiansen, M.Sc.
Senior Research Officer—F. J. Kerr, M.Sc.
Senior Research Officer—H. C. Minnett, B.Sc., B.E.
Research Officer—Miss R. Payne-Scott, M.Sc.
Research Officer—A. B. Thomas, M.A.
Research Officer—R. N. Bracewell, B.Sc., B.E., Ph.D.
Research Officer—B. Y. Mills, B.Sc., M.E.
Research Officer—S. F. Smerd, B.Sc.
Research Officer—C. A. Shain, B.Sc.
Research Officer—J. P. Wild, B.A.
Research Officer—F. F. Gardner, B.Sc., B.E.
Research Officer—E. K. Bigg, M.Sc.
Technical Officer—C. S. Higgins.
Technical Officer—J. V. Hindman.
Technical Officer—K. R. McAlister, A.S.T.C., Elec. Eng.Mech.Eng.
Technical Officer—G. J. Stanley, A.S.T.C., Elec. Eng.
Technical Officer—J. D. Murray, B.Eng.Sc.
Technical Officer—A. G. Little.
Technical Officer—H. R. Harant, A.S.T.C.

*Rain and Cloud Physics*—

Senior Research Officer—J. Warner, B.Sc., B.E.
Senior Research Officer—P. Squires, M.A.
Senior Research Officer—E. J. Smith, M.B.E., B.Sc. (Eng.).
Research Officer—E. E. Adderley, B.Sc.
Research Officer—G. A. Day.
Research Officer—H. L. Humphries, B.Sc., B.E.
Research Officer—N. R. Labrum, B.Sc.
Research Officer—R. S. Styles, B.Sc., B.E.
Research Officer—K. H. Holywell, B.Sc.
Research Officer—J. W. Telford, B.Sc.
Research Officer—Mrs. B. Smith, B.Sc. (part-time).
Senior Technical Officer—G. T. Miles.
Technical Officer—T. D. Newnham.
Technical Officer—F. W. Campbell.
Technical Officer—R. C. Baker.
Technical Officer—K. A. Davidson.
Technical Officer—D. C. Dunn.
Technical Officer—L. F. Clague.
Technical Officer—K. J. Heffernan.

Technical Officer—H. E. Miller.
Technical Officer—N. S. Thorndike.
Technical Officer—S. A. Pett.
Technical Officer—C. F. Attwood.

*Mathematical Physics—*

Senior Research Officer—T. Pearcey, B.Sc.
Research Officer—Miss M. A. Adamson, B.A., Dip.Ed.

*Electronic Computing—*

Senior Research Officer—M. Beard, B.Sc., B.E.
Senior Research Officer—B. F. C. Cooper, B.Sc., B.E.
Research Officer—R. D. Ryan, B.Sc., B.E.
Research Officer—G. W. Hill, B.Sc.
Technical Officer—F. C. Tonking, A.S.T.C.
Technical Officer—J. Algie, A.S.T.C.

*Test Room—*

Technical Officer—G. A. Wells, A.S.T.C.
Technical Officer—O. C. Turner.

*Radio Navigation—*

Senior Research Officer—L. L. McCready, B.Sc., B.E.
Research Officer—J. G. Downes, B.Sc.
Research Officer—D. E. Yabsley, B.Sc., B.E.
Technical Officer—P. T. Hedges, A.S.T.C.
Technical Officer—K. V. Sheridan.

*Vacuum Physics—*

Technical Officer—F. C. James.

*Officers Abroad—*

Research Officer—J. G. Bolton, B.A.
Research Officer—K. C. Westfold, M.A., B.Sc.
Research Officer—J. A. Roberts, M.Sc.

*Photographic—*

Technical Officer—R. S. B. Millett.
Technical Officer—A. J. A. Tolliday.

*Office and Publications—*

Miss S. Atkinson, B.A.
Mrs. A. Purdy, B.Sc.

*Engineering Services—*

Assistant Technical Secretary—J. P. Eagles.
Chief Draughtsman—F. M. Carter.
Works Supervisor—H. Byers.

### 31. Division of Soils.

(Head-quarters: Waite Agricultural Research Institute, Adelaide.)

Chief—J. K. Taylor, B.A., M.Sc., B.Sc.Agr.
Principal Research Officer—C. G. Stephens, D.Sc.
Principal Research Officer—T. J. Marshall, M.Ag.Sc., Ph.D.
Principal Chemist—C. S. Piper, D.Sc.
Senior Research Officer—G. D. Hubble, B.Ag.Sc.
Senior Research Officer—R. Smith, B.Ag.Sc.
Research Officer—B. E. Butler, B.Agr.Sc.
Research Officer—A. C. Oertel, M.Sc.
Research Officer—A. E. Martin, B.Sc., F.R.I.C.
Research Officer—A. G. Turton, B.Sc.
Research Officer—G. D. Aitchison, B.E.
Research Officer—K. D. Nicolls, B.Ag.Sc., B.Sc.
Research Officer—E. J. Johnston, B.Sc.Agr.
Research Officer—J. T. Hutton, B.Sc., A.S.A.S.M.
Research Officer—R. Brewer, B.Sc.
Research Officer—K. H. Northcote, B.Ag.Sc.
Research Officer—G. Blackburn, B.Agr.Sc.
Research Officer—G. A. Stewart, B.Ag.Sc.
Research Officer—H. C. T. Stace, B.Sc.
Research Officer—B. M. Tucker, B.Sc.
Research Officer—J. R. Harris, B.Sc.
Research Officer—K. Norrish, M.Sc. (abroad).
Research Officer—G. B. Stirk, B.Sc.
Research Officer—J. P. Quirk, B.Sc.Agr.
Research Officer—Miss M. P. Read, B.Sc., Ph.D.
Research Officer—R. S. Beckwith, B.Sc.
Research Officer—M. Raupach, B.Sc.
Research Officer—J. W. Holmes, B.Sc.
Research Officer—C. G. Gurr, B.Sc.
Research Officer—J. R. Sleeman, B.Ag.Sc.
Research Officer—G. M. Dimmock, B.Sc.
Research Officer—J. E. Cox, B.Sc.Agr.
Research Officer—E. W. Radoslovich, B.Sc.
Research Officer—B. W. Vitnell, B.Sc.
Research Officer—G. G. Beckmann, B.Sc.
Technical Officer—A. D. Haldane, B.Sc.
Technical Officer—R. M. Tavender.
Technical Officer—R. M. McKenzie.
Technical Officer—R. Reeve.
Technical Officer—W. H. Litchfield, B.Sc.Agr.
Technical Officer—C. H. Thompson.
Technical Officer—L. W. Pym.
Technical Officer—A. R. P. Clarke.
Technical Officer—A. W. Palm.
Draughtsman—P. D. Hooper.
Draughtsman—R. B. Ewers.
Rubber Investigations—R. E. Shapter, A.A.C.I.

### 32. Division of Tribophysics.

(Head-quarters: University of Melbourne.)

Chief—W. Boas, D.Ing., M.Sc.
Senior Research Officer—T. V. Krok, B.E.
Senior Research Officer—M. F. R. Mulcahy, D.Phil., M.Sc., A.G.Inst.Tech.
Research Officer—E. B. Greenhill, Ph.D., M.Sc.
Research Officer—A. J. W. Moore, Ph.D., B.Sc.
Research Officer—R. G. Vines, M.Sc.
Research Officer—J. K. Mackenzie, Ph.D., B.A., B.Sc.
Research Officer—J. S. Bowles, M.Sc. (abroad).
Research Officer—M. E. Hargreaves, Ph.D., B.Met.E.
Research Officer—D. Michell, B.E.E.
Research Officer—M. J. Ridge, M.Sc.
Research Officer—G. W. West, B.E.E., B.Sc.
Research Officer—L. M. Clarebrough, B.Met.E., M.Eng.Sc.
Research Officer—A. J. Davis, B.Eng.
Research Officer—P. J. Fensham, M.Sc.
Research Officer—D. S. Kemsley, B.Sc., F.M.T.C.
Research Officer—Miss M. J. Newing, Ph.D., B.Sc.
Research Officer—J. F. Nicholas, B.A., B.Sc.
Research Officer—G. J. Ogilvie, B.Met.E., M.Eng.Sc. (abroad).
Research Officer—J. V. Sanders, Ph.D., B.Sc.
Research Officer—Mrs. H. M. C. Sosnowsky, Ph.D.
Research Officer—J. A. Spink, B.Sc.
Technical Officer—F. H. Hay.
Technical Officer—R. W. Coventry.
Technical Officer—D. J. Norris.
Technical Officer—G. R. Perger, F.M.T.C.
Technical Officer—R. G. Sherwood, A.M.T.C.
Technical Officer—W. J. Tegart, A.M.T.C.
Part-time Officer—I. C. Watt, B.Sc.
Part-time Officer—S. R. McDonald, B.Sc.
Goldsmith Dominion (Travelling) Scholar—T. Broom, M.A.

### 33. Wild Life Survey Section.

(Head-quarters: Canberra, Australian Capital Territory.)

Officer-in-Charge—F. N. Ratcliffe, B.A.
Research Officer—Miss M. Lazarus, B.Sc.
Research Officer—J. le G. Brereton, B.Sc.
Research Officer—B. V. Fennessy, B.Agr.Sc.
Research Officer—K. Myers, B.Sc.
Technical Officer—J. H. Calaby.

### 34. Wool Textile Research Laboratories.

Senior Officer-in-Charge—F. G. Lennox, D.Sc.

*At Wool Textile Research Laboratory, Melbourne—*
*Biochemistry Unit, 572 Flinders-lane, Melbourne—*

Officer-in-Charge—F. G. Lennox, D.Sc.
Senior Research Officer—H. Lindley, B.A., Ph.D

Senior Research Officer—W. G. Crewther, M.Sc. (abroad).
Research Officer — W. J. Ellis, A.S.T.C. (seconded).
Research Officer—T. A. Pressley, B.Sc.
Research Officer—Miss M. E. Maxwell, M.Sc.
Research Officer—J. M. Gillespie, M.Sc.
Research Officer—M. A. Jermyn, M.Sc., Ph.D.
Research Officer—S. J. Leach, B.Sc., Tech., Ph.D.
Research Officer—J. M. Swan, B.Sc., Ph.D.
Research Officer—E. F. Woods, M.Sc., A.M.T.C.
Research Officer—Mrs. E. S. Rodwell, Ph.D.
Research Officer—D. H. Simmonds, M.Sc. (abroad).

*Solvent Degreasing Investigations, Marbyrnong*—
Principal Research Officer—E. J. Drake.
Draughtsman—E. E. Slade.
Technical Officer—E. Armstrong.

*At Wool Textile Research Laboratory, Sydney*—

*Physics and Engineering Unit,* 119 *Phillip-street, Sydney*—
Officer-in-Charge—V. D. Burgmann, B.Sc., B.E.

*Carbonizing Investigations,* 17 *Randle-street, Sydney*—
Senior Research Officer—M. R. Freney, B.Sc.

*At Wool Textile Research Laboratory, Geelong*—
Officer-in-Charge—M. Lipson, B.Sc., Ph.D.
Technical Secretary and Wool Textile Liaison Officer—N. A. Whiffen, F.S.T.C.
Senior Research Officer—D. L. C. Jackson, B.Sc.
Research Officer—N. K. Boardman, M.Sc.
Research Officer—E. A. Niemanis, Dipl.Chem. (Stuttgart).
Research Officer—Miss A. M. Dingle, B.Sc.
Technical Officer—Miss R. J. Hope, A.G.Inst.Tech.
Technical Officer—A. Gray, B.Sc.
Assistant Librarian—Miss D. Norman.

## XXXIV. PUBLICATIONS.

The following papers have been published during the year:—

### 1. Division of Animal Health and Production.

Austin, C. R. (1949).—The functions of the endocrine system in pregnancy. *Aust. Vet. J.* 25:190-3.

Durie, P. H. (1949).—A preliminary note on the life cycle of *Paramphistomum cotylophorum* (Fischoeder, 1901) and *P. cervi* (Schrank, 1790) (Trematoda: Paramphistomatidae). *Aust. Vet. J.* 25:209.

Ferguson, K. A. (1949).—The effect of sympathectomy on wool growth. *Aust. J. Sci. Res.* B, 2:438-43.

Franklin, M. C., Reid, R. L., *and* Johnstone, I. L. (1948).—Studies on dietary and other factors affecting the serum-calcium levels of sheep. Parts I.-VI. Coun. Sci. Industr. Res. Aust. Bull. No. 240.

Gordon, H. McL. (1949).—Epidemiology and the efficient parasite. *Rep. Aust. N.Z. Ass. Adv. Sci.* 27:131-41.

Gordon, H. McL. (1950).—Some aspects of parasitic gastro-enteritis of sheep. *Aust. Vet. J.* 26:14-28, 46-52, 65-72, 93-8.

Gregory, T. S. (1949).—The accuracy of diagnostic methods used in the detection of tuberculous cattle. *Aust. Vet. J.* 25:138-52.

Hamilton, F. J. (1950).—A technique for the collection of nematodes from the alimentary tract of sheep. *Aust. J. Agric. Res.* 1:93-8.

Jennings, A. C. (1949).—The biochemical characterization of a serologically active lipid fraction of the nematode, *Haemonchus contortus. Aust. J. Sci. Res.* B, 2:408-20.

Kennedy, J. F., *and* Bettenay, R. A. (1950).—Mating and lambing in an experimental flock of merino sheep. *Aust. J. Agric. Res.* 1:76-92.

Lazarus, Marian (1950).—The respiratory metabolism of helminths. *Aust. J. Sci. Res.* B, 3: 245-50.

Massey, V., *and* Rogers, W. P. (1950).—The intermediary metabolism of nematode parasites. 1. The general reactions of the tricarboxylic acid cycle. *Aust. J. Sci. Res.* B, 3:251-64.

Massey, V., *and* Rogers, W. P. (1950).—Fluoro acetate and the tricarboxylic acid cycle in nematode parasites. *Nature* 165:681.

Reid, R. L. (1950).—Studies on the carbohydrate metabolism of sheep. I. The range of blood-sugar values under several conditions. *Aust. J. Agric. Res.* 1:182-99.

Reid, R. L. (1950).—The utilization of acetic and propionic acids in sheep. *Nature* 165: 448.

Riches, J. H., *and* Johnstone, I. L. (1949).—An experiment to determine the relative growth and productivity of rams and wethers under identical field conditions. *Aust. Vet. J.* 25:270-2.

Riek, R. F., Hardy, M. H., Lee, D. H. K.,* *and* Carter, H. B. (1950).—The effect of the dietary plane upon the reactions of two breeds of sheep during short exposures to hot environments. *Aust. J. Agric. Res.* 1:217-30.

Roberts, F. H. S. (1950).—The tail-switch louse of cattle *Haematopinus quadripertusus* Fahrenholz. *Aust. Vet. J.* 26:136-8.

Roberts, F. H. S., *and* O'Sullivan, P. J.† (1950).—Methods for egg counts and larval cultures for strongyles infesting the gastro-intestinal tract of cattle. *Aust. J. Agric. Res.* 1:99-102.

Rogers, W. P. (1949).—The biological significance of haemoglobin in nematode parasites. I. Characteristics of the purified pigments. *Aust. J. Sci. Res.* B, 2:287-303.

Rogers, W. P. (1949).—The biological significance of haemoglobin in nematode parasites. II. Properties of the haemoglobins as studied in the living parasites. *Aust. J. Sci. Res.* B, 2:399-407.

Rogers, W. P. (1949).—On the relative importance of aerobic metabolism in small nematode parasites of the alimentary tract. I. Oxygen tensions in the normal environment of the parasites. II. The utilization of oxygen at low pressures by small nematode parasites of the alimentary tract. *Aust. J. Sci. Res.* B, 2:157-74.

Scott, Marion T. (1949).—The failure of benzene hexachloride to control itch mite (*Psorergates ovis*). *Aust. Vet J.* 25:300-1.

Titchen, D. A., Steel, J. D.,‡ *and* Hamilton, F. J. (1949).—Clinical observations on thiobarbiturate anaesthesia in sheep. *Aust. Vet. J.* 25:257-61.

Turner, A. W. (1949).—Bacterial oxidation of arsenite. *Nature* 164:76.

### 2. Atomic Physics.

*Tracer Elements Unit.*

Oddie, T. H., *and* Scott R. K. (1949).—External measurement of radio-iodine in the thyroid gland. *Brit. J. Radiol.* 22:698.

### 3. Division of Biochemistry and General Nutrition.

Marston, H. R. (1947).—The assessment of minor element deficiencies in plants and animals. *Proc. XI. Int. Congr. Pure Appl. Chem.*

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* Johns Hopkins University, Baltimore 18, Md., U.S.A.; formerly University of Queensland.

† Animal Health Station, Yeerongpilly, Queensland Department of Agriculture and Stock.

‡ Lecturer in Veterinary Medicine, University of Sydney.

Iarston, H. R. (1949).—The organization and work of the Division of Biochemistry and General Nutrition of C.S.I.R.O. *Proc. Roy. Soc.* A, 199: 273-94.

Iarston, H. R., *and* Lee, H. J. (1949).—Primary site of the action of cobalt in ruminants. *Nature* 164: 529-30.

### 4. Division of Building Research.

Iutson, J. M. (1949).—Laying of magnesium oxychloride flooring. *Build. Construct.* 25(1274): 3-4, (1275): 5-7.

Taylor, W. H. (1949).—Foamed concrete. *Construct. Rev.* 22 (6): 11-18, 44.

### 5. Commonwealth Research Station (Murray Irrigation Areas).

Brock, R. D., *and* Giles, J. E. (1949).—Control of root-knot nematode in tomatoes by soil fumigation. *J. Aust. Inst. Agric. Sci.* 15: 154-7.

### 6. Dairy Research Section.

Loftus Hills, G. (1949).—Oxidation in the fat phase of dairy products. 12th Int. Dairy Congr. 2: 302.

Loftus Hills, G. (1949).—Temperature control in the storage of dairy products. 12th Int. Dairy Congr. 6: 166.

Wiley, W. J., *and* Loftus Hills, G. (1949).—Pseudo fat-globules in butter concentrate. 12th Int. Dairy Congr. 3: 189.

### 7. Division of Electrotechnology.

Churchward, Vivienne R., Gibson, N. A., Meakins, R. J., *and* Mulley, Joan W. (1950).—The preparation of a series of (±)-*n*-eicosanols and *n*-eicosanones. *J. Chem. Soc.* 197: 959-60.

Dobbie, L. G. (1950).—Investigations into tropic proofing of electrical materials 1943-46. I. The protection of electronic equipment for use under humid tropical conditions. *Aust. J. Appl. Sci.* 1: 80.

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## XXXV. FINANCE.

### 1. Expenditure.

The statement of expenditure from 1st July, 1949, to 30th June, 1950, is as follows:—

| | £ | £ | £ |
|---|---|---|---|
| (*a*) Salaries and contingencies | .. | .. | 169,977* |
| (*b*) Investigations— | | | |
| (i) Animal Health and Production Problems | .. | 238,988 | |
| *Less* contributions from— | | | |
| Wool Industry Fund | 4,057 | | |
| Wool Research Fund | 74,508 | | |
| Commonwealth Bank | 2,025 | | |
| Queensland Government | 1,000 | | |
| Australian Dairy Produce Board | 2,000 | | |
| Australian Meat Board | 1,000 | | |
| Australian Wool Board | 166 | | |
| Ian McMaster Bequest | 592 | | |
| Alexander Fraser Memorial Fund | 300 | | |
| Burdekin Bequest—Drought Feeding | 2,485 | | |
| Revenue Funds— | | | |
| Regional Pastoral Laboratory, Armidale | 3,000 | | |
| Burdekin Bequest | 1,010 | | |
| Poultry Breeding | 3,000 | | |
| Parkville | 729 | | |
| Vaccine | 1,400 | | |
| Contagious Pleuro-pneumonia | 1,600 | | |
| Tooradin Field Station | 1,144 | | |
| Parasitology—McMaster Laboratory | 229 | | |
| Oestrus | 760 | | |
| Toxaemic Jaundice—Barooga | 504 | | |
| Toxaemic Jaundice—Parkville | 339 | | |
| Mastitis | 1,856 | | |
| McMaster Field Station | 1,380 | | |
| Gilruth Plains Field Station | 9,996 | | |
| | | 115,080 | |
| | | | 123,908 |
| (ii) Biochemistry and General Nutrition Problems | .. | 71,272 | |
| *Less* contributions from— | | | |
| Commonwealth Bank | 675 | | |
| Wool Research Fund | 16,645 | | |
| Wool Industry Fund | 15,594 | | |
| Australian Wool Board (balance of old grants) | 330 | | |
| | | 33,244 | |
| | | | 38,028 |
| (iii) Plant Problems—Division of Plant Industry | .. | 223,926 | |
| *Less* contributions from— | | | |
| Department of Post-war Reconstruction | 7,102 | | |
| West Australian Golf Association | 52 | | |
| Wool Industry Fund | 9,230 | | |
| Wool Research Fund | 33,938 | | |
| Plant Industry Revenue Fund | 1,111 | | |
| | | 51,433 | |
| | | | 172,403 |
| (iv) Entomology Problems | .. | 73,438 | |
| *Less* contributions from— | | | |
| Wool Research Fund | 259 | | |
| | | 259 | |
| | | | 73,179 |
| (v) Soils and Irrigation Problems of the Irrigation Settlements — | | | |
| (*a*) Citricultural—Research Station, Griffith | 43,273 | | |
| *Less* contributions from—— | 3,463 | | |
| | | 39,810 | |
| New South Wales Water Conservation and Irrigation Commission | 2,000 | | |
| Griffith Research Station Revenue Fund | 1,463 | | |
| (*b*) Viticultural—Research Station, Merbein | 24,348 | | |
| *Less* contributions from—— | 3,688 | | |
| | .. | 20,660 | |
| | | | 60,470 |
| Dried Fruits Control Board | 1,408 | | |
| Mildura Co-operative Fruit Company | 137 | | |
| Irymple Packing Company | 136 | | |
| Red Cliffs Co-operative Fruit Company | 136 | | |
| Aurora Packing Company | 136 | | |
| Merbein Station Revenue | 1,735 | | |
| (vi) Soil Problems | .. | 60,775 | |
| *Less* contributions from— | | | |
| Commonwealth Bank | 1,500 | | |
| | .. | 1,500 | |
| | | | 59,275 |
| Unapportioned overseas expenditure on Soils and Irrigation Investigations | .. | .. | 4,084 |
| (vii) Food Preservation and Transport Problems | .. | 80,978 | |
| *Less* contributions from— | | | |
| Commonwealth Bank | 1,800 | | |
| New South Wales Department of Agriculture | 1,292 | | |
| Metropolitan Meat Industry Commission | 500 | | |
| Queensland Meat Industry Board | 850 | | |
| Australian Meat Board | 375 | | |

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* The main items of expenditure under this heading are salaries of the Administrative Staff at the Organization's Head Office; salaries and expenses of officers at the Liaison Offices in London and Washington; staff and upkeep of State Committees; travelling expenses of Head Office Staff; and printing and general office expenditure.

| | £ | £ | £ |
|---|---|---|---|
| Alfred Lawrence and Company | 74 | | |
| Lewis Berger and Son | 25 | | |
| Ungar's Peanuts Limited | 10 | | |
| Australian Egg Board | 435 | | |
| Egg Investigations Revenue Fund | 146 | | |
| Food Preservation Revenue Fund | 75 | | |
| Fruit Juices Revenue Fund | 12 | | |
| | | 5,594 | |
| | | | 75,384 |
| (viii) Forest Products Problems | .. | 145,568 | |
| *Less* contributions from— | | | |
| Australian Paper Manufacturers Limited | 500 | | |
| Associated Pulp and Paper Mills Limited | 500 | | |
| New Zealand Forest Products Limited | 250 | | |
| Australian Newsprint Mills Limited | 500 | | |
| Commonwealth Bank | 1,500 | | |
| Forest Products Revenue Fund | 1,279 | | |
| | | 4,529 | |
| | | | 141,039 |
| (ix) Mining and Metallurgy | .. | 16,351 | |
| *Less* contributions from— | | | |
| Australian Institute of Mining and Metallurgy | 500 | | |
| | | 500 | |
| | | | 15,851 |
| (x) Radio Research | .. | 21,865 | |
| *Less* contributions from— | | | |
| Postmaster-General's Department | 4,500 | | |
| Department of Army, Navy, and Air | 10,813 | | |
| | | | 6,552 |
| | | 15,313 | |
| (xi) Research Services | .. | 58,893 | |
| *Less* contributions from— | | | |
| Information Service Revenue Fund | 77 | | |
| Foreign Journal Service Fund | 9 | | |
| | | 86 | |
| | | | 58,807 |
| (xii) Industrial Chemistry | .. | 186,603 | |
| *Less* contributions from— | | | |
| National Gas Association | 600 | | |
| Cement and Concrete Association | 1,500 | | |
| Wool Industry Fund | 3,711 | | |
| Wool Research Fund | 85 | | |
| | | 5,896 | |
| | | | 108,707 |
| (xiii) Fisheries Investigations | .. | 111,273 | |
| *Less* contributions from— | | | |
| New South Wales Department of Chief Secretary | 250 | | |
| Oyster Revenue Fund | 140 | | |
| | | 390 | |
| | | | 110,883 |
| (xiv) Mathematical Statistics | .. | .. | 17,841 |
| (xv) National Standards Laboratory | .. | .. | 216,460 |
| (xiv) Tribophysics | .. | .. | 39,269 |
| (xvii) Building Research | .. | .. | 82,790 |
| (xviii) Flax Research | .. | .. | 22,077 |
| (xix) Radiophysics Research | .. | .. | 157,059 |
| (xx) Metallurgical Research | .. | .. | 4,891 |
| (xxi) Nuclear Energy Research | .. | .. | 33,914 |
| (xxii) Meteorological Physics | .. | .. | 21,671 |
| (xxiii) Dairy Research | .. | .. | 8,825 |
| (xxiv) Wool Textile Research | .. | 83,265 | |
| *Less* contributions from— | | | |
| Wool Research Fund | 61,308 | | |
| Wool Industry Fund | 21,924 | | |
| | | 83,232 | |
| | | | 33 |
| (xxv) Fuel Research | .. | .. | 35,944 |
| (xxvi) Miscellaneous— | | | |
| (*a*) Wild Life Survey | .. | 6,199 | |
| (*b*) Oenological Research | .. | 2,319 | |
| (*c*) Various | .. | 8,133 | |
| | | 16,651 | |
| *Less* contributions from— | | | |
| Australian Wine Board | 999 | | |
| Wool Research Fund | 2,619 | | |
| George Aitken Pastoral Research Trust Fund | 500 | | |
| | | 4,118 | |
| | | | 12,533 |
| (xxvii) Unforeseen and Urgent— | | | |
| Total of Item (*b*)—Investigations | .. | .. | 1,773,967 |
| (*c*) Grants— | | | |
| (i) Grant to Leather Research Association | .. | 5,000 | |
| (ii) Overseas Research Studentships | .. | 27,313 | |
| | | 32,313 | |
| *Less* contributions from— | | | |
| Wool Research Fund | 9,396 | | |
| | | 9,396 | |
| | | | 22,917 |

## 2. Contributions and Donations.

The following statement shows the receipts and disbursements during the year 1949-50 of the funds provided by outside bodies and recorded in the special account entitled "The Specific Research Fund" (formerly "The Specific Purposes Trust Account"):—

| | Receipts 1949-50 and balances brought forward from 1948-49. | Expenditure 1949-50. |
|---|---|---|
| | £ | £ |
| Wool Industry Fund Account | 59,800 | 54,516* |
| Commonwealth Bank (Animal Health and Production, Horticultural, Food Preservation and Transport, and Forest Products Investigations) | 7,500 | 7,500 |
| Australian Wool Board (Animal Health and Production Investigations—Sheep Research) | 2,497 | 496 |
| Australian Dairy Produce Board (Mastitis Investigations) | 2,000 | 2,000 |
| George Aitken Pastoral Research Trust (Animal Health and Production Investigations) | 500 | .. |
| Queensland Government Cattle Research (Animal Health and Production Investigations — Sheep Research) | 1,000 | 1,000 |
| Australian Meat Board (Toxaemic Jaundice Investigations, Barooga, New South Wales) | 1,000 | 1,000 |
| Australian Meat Board (Caseous Lymphadenitis Investigations — Animal Health and Production) | 412 | .. |
| Alexander Fraser Memorial Fund | 300 | 300 |
| C.P.P. Fairbairn (Animal Health and Production Investigations—Foot-rot Control | 30 | .. |
| Estate of the late Captain Ian McMaster (Animal Health and Production Investigations) | 799 | 799 A |
| West Australian Golf Association (Plant Industry Investigations) | 100 | 76 B |
| Department of Post-war Reconstruction — Northern Australia Regional Survey (Division of Plant Industry) | 8,915 | 8,275 C |
| United Graziers' Association of Queensland — Buffalo Fly and Cattle Tick Investigations (Economic Entomology) | 172 | .. |
| Burdekin Bequest (Drought Feeding Investigations) | 2,485 | 2,485 |
| New South Wales Water Conservation and Irrigation Commission (Maintenance of Griffith Research Station) | 2,000 | 2,000 |
| Murrumbidgee Irrigation Area Executive Committee Project Farm (Griffith Research Station) | 100 | .. |
| Mildura Co-operative Fruit Company (Dried Vine Fruits Investigations, Merbein) | 218 | 175 D |
| Irymple Packing Company (Dried Vine Fruits Investigations, Merbein) | 218 | 175 D |
| Red Cliffs Co-operative Fruit Company (Dried Vine Fruits Investigations, Merbein) | 218 | 175 D |
| Aurora Packing Company (Dried Vine Fruits Investigations, Merbein) | 218 | 175 D |
| Dried Fruits Control Board (Dried Fruits Investigations) | 1,600 | 1,408 |
| Nyah-Woorinen Dried Fruits Inquiry Committee (Dried Fruits Investigations) | 353 | .. |
| Australian Meat Board (Meat Investigations) | 500 | 500 E |
| Metropolitan Meat Industry Commissioner of New South Wales (Meat Investigations) | 500 | 500 |
| Queensland Meat Industry Board (Meat Investigations) | 850 | 850 |
| New South Wales Department of Agriculture (Food Investigations) | 1,000 | 1,000 |
| A. Lawrence and Co. (Division of Food Preservation and Transport) | 74 | 74 |
| W. Angliss Limited (Division of Food Preservation and Transport) | 38 | .. |
| L. Berger and Sons (Division of Food Preservation and Transport) | 75 | 25 |
| Batlow Packing House Co-operative Limited (Division of Food Preservation and Transport—Fruit Juice Investigations) | 600 | .. |
| Ungars Peanuts Proprietary Limited (Division of Food Preservation and Transport—Canning Investigations) | 10 | 10 |
| Various Contributors (Division of Food Preservation and Transport —Fruit Juice Investigations) | 40 | 12 |
| Australian Egg Board (Division of Food Preservation and Transport —Egg Investigations) | 435 | 435 |
| New South Wales Department of Agriculture—Quick Freezing of Fruit and Vegetables (Division of Food Preservation and Transport) | 475 | 416 F |
| Australian Paper Manufacturers Limited (Paper Pulp Investigations) | 500 | 500 |
| Associated Pulp and Paper Mills Limited (Paper Pulp Investigations) | 500 | 500 |
| Australian Newsprint Mills Proprietary Limited (Paper Pulp Investigations) | 500 | 500 |
| New Zealand Forest Products Company Limited (Paper Pulp Investigations) | 250 | 250 |
| Boracure New Zealand Limited (Vapour Drying Work) | 600 | .. |
| Sundry Contributors (Forest Products Investigations) | 2,335 | 1,279 |
| Miscellaneous Contributors (Division of Forest Products—Timber Seasoning Work) | 10 | .. |
| Miscellaneous Contributors (Division of Forest Products—Veneer and Gluing Work) | 8 | .. |
| Victorian Railways—High Pressure Test—Railway Sleepers (Division of Forest Products) | 1,180 | .. |
| Australasian Institute of Mining and Metallurgy (Mineragraphic Investigations) | 500 | 500 |
| Postmaster-General's Department (Radio Research) | 4,500 | 4,500 |
| Departments of Army, Navy, and Air (Radio Research) | 10,913 | 10,913 G |
| Sundry Contributions (Foreign Journal Service) | 9 | 9 |
| New South Wales Government (Fisheries Investigations) | 250 | 250 |
| Drug Houses of Australia (Division of Fisheries—Agar Production) | 25 | .. |
| Commonwealth Fertilizers and Chemicals (Industrial Chemistry) | 300 | .. |
| National Gas Association (Gas Investigations—Industrial Chemistry) | 1,933 | 600 |
| Australian Cement Manufacturers (Cement Investigations—Industrial Chemistry/Soils) | 1,500 | 1,500 |

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* Expended as follows:—Buildings at Armidale, £1,946. Construction of dams at Armidale, £338. Installation of electricity and phone at Armidale, £277. Laboratory building and site at Prospect, £20. Boundary fencing and dams at Prospect, £741. Construction of roadway at Armidale, £424. Acquisition of property "Saumarez", £106. Re-erection of building at Cobram, £206. Buildings at Deniliquin, £7,529. Buildings at Trangie, £1,701. Erection of Biochemistry Laboratory, £3,711. Erection of Nutrition Laboratory, £14,341. Electrical installations at Glenthorne, £325. Concrete storage tank, £928. Purchase and re-erection of three Army Huts, £7,935. Alterations at Maribyrnong, £200. Acquisition of home sites at Geelong, £1,528. Air conditioning and gas installation, Geelong, £250. Acquisition of property "Quamby", £12,010.

A. Includes £207 on account of 1948-49 expenditure.
B. Includes £24 on account of 1948-49 expenditure.
C. Includes £1,173 on account of 1948-49 expenditure.
D. Includes £39 on account of 1948-49 expenditure.

E. Includes £125 on account of 1948-49 expenditure.
F. Includes £125 on account of 1948-49 expenditure.
G. Includes £100 on account of 1948-49 expenditure.

| | Receipts 1949-50 and balances brought forward from 1948-49. | Expenditure 1949-50. |
|---|---|---|
| | £ | £ |
| Apple and Pear Board—Thrips Investigations | 77 | .. |
| Sundry Contributors (Commonwealth Scientific and Industrial Research Organization—Publications) | 24 | .. |
| Various Contributors (Division of Industrial Chemistry | 691 | .. |
| Wool Scourers, Carbonizers and Fellmongers Federation of Australia (Division of Industrial Chemistry) | 3,000 | .. |
| Various Contributors (Foundry Sands Investigations—Division of Industrial Chemistry | 28 | .. |
| Commonwealth Aircraft Corporation (Division of Metrology, N.S.L.) | 1,167 | .. |
| Australian Wine Board—Oenological Research | 1,048 | 1,048 H |
| George Aitken Pastoral Research Trust—Rabbit Investigations | 875 | 500 |
| Revenue Fund—Fleece Analysis Laboratory (Animal Health and Production Investigations) | 300 | .. |
| Revenue Fund—Toxaemic Jaundice Investigations (Animal Health and Production Investigations | 1,577 | 339 |
| Revenue Fund—Contagious Pleuro-pneumonia Investigations (Animal Health and Production Investigations) | 2,188 | 2,147 I |
| Revenue Fund—Oestrus Experiment (Animal Health and Production Investigations) | 1,086 | 760 |
| Revenue Fund—Sale of Contagious Pleuro-pneumonia Vaccine (Animal Health and Production Investigations) | 3,625 | 3,585 J |
| Revenue Fund—Cobram Field Station (Animal Health and Production Investigations) | 762 | .. |
| Revenue Fund—Burdekin Bequest (Animal Health and Production Investigations) | 1,297 | 1,010 |
| Revenue Fund—Anaplasmosis Investigations (Animal Health and Production Investigations) | 96 | .. |
| Revenue Fund—Parkville Laboratory (Animal Health and Production Investigations) | 900 | 900 K |
| Revenue Fund—Tooradin Field Station (Animal Health and Production Investigations) | 1,534 | 1,144 |
| Revenue Fund—Poultry Breeding Investigations, Werribee (Animal Health and Production Investigations) | 3,714 | 3,194 L |
| Revenue Fund—Werribee Farm Mastitis Investigations (Animal Health and Production Investigations) | 4,782 | 1,856 |
| Revenue Fund—Drought Feeding Investigations, Werribee (Animal Health and Production Investigations) | 63 | .. |
| Revenue Fund—National Field Cunnamulla, Queensland (Animal Health and Production Investigations) | 19,201 | 9,996 |
| Reserve Fund — National Field Station, "Gilruth Plains", Cunnamulla, Queensland (Animal Health and Production Investigations) | 10,000 | .. |
| Revenue Fund—Bacteriological Investigations (Animal Health and Production Investigations) | 20 | 20 M |
| Revenue Fund—Parasitological Investigations (Animal Health and Production Investigations) | 2,297 | 230 |
| Revenue Fund—Wool Biology Investigations (Animal Health and Production Investigations) | 96 | .. |
| Revenue Fund—Regional Pastoral Research Station (Animal Health and Production Investigations) | 13,572 | 3,000 |
| General Donations—Building Research Section | 26 | .. |
| Revenue Fund—Infertility, F. D. McMaster Field Station (Animal Health and Production Investigations) | 4,278 | 1,511 N |
| Revenue Fund—Veterinary Parasitology Laboratory (Animal Health and Production Investigations) | 81 | .. |
| Revenue Fund—Toxaemic Jaundice Investigations, Barooga, New South Wales (Animal Health and Production Investigations) | 2,043 | 504 |
| Revenue Fund—Nutrition Laboratory (Biochemistry and General Nutrition Investigations) | 6,947 | .. |
| Revenue Fund—Plant Industry Investigations | 6,416 | 1,112 |
| Revenue Fund—Stanthorpe Field Station (Plant Industry Investigations) | 3,292 | .. |
| Revenue Fund—Glen Lossie Field Station (Plant Industry Investigations) | 1,840 | .. |
| Revenue Fund — Deniliquin Regional Pastoral Laboratory (Plant Industry Investigations) | 2,693 | .. |
| Revenue Fund—Cooper Laboratory (Plant Industry Investigations) | 141 | .. |
| Revenue Fund—Entomological Investigations | 1,140 | .. |
| Revenue Fund—Griffith Research Station (Citricultural Investigations) | 3,572 | 1,463 |
| Revenue Fund—Merbein Research Station (Viticultural Investigations) | 12,476 | 1,735 |
| Revenue Fund—Division of Food Preservation and Transport | 100 | 75 |
| Revenue Fund—Egg Investigations (Division of Food Preservation and Transport) | 218 | 146 |
| Revenue Fund—Mining and Metallurgy | 14 | .. |
| Revenue Fund—Ore-dressing Investigations | 1,073 | .. |
| Revenue Fund — Fisheries Investigations | 458 | .. |
| Revenue Fund—Oyster Investigations | 141 | 141 |
| Revenue Fund—Physics | 1,215 | .. |
| Revenue Fund—National Standards Laboratory | 35 | .. |
| Revenue Fund—Metrology | 2,460 | .. |
| Revenue Fund—Dairy Investigations | 25 | .. |
| Revenue Fund—Electrotechnology | 385 | .. |
| Revenue Fund — Industrial Chemistry | 538 | .. |
| Revenue Fund—Radiophysics | 52 | .. |
| Revenue Fund—Tribophysics | 1 | .. |
| Revenue Fund—Merbein Research Station—Production of Pyrethrum | 185 | .. |
| Revenue Fund—Information Service | 77 | 77 |
| Revenue Fund—Wool Wax Report—Royalties (Information Service) | 6 | .. |
| | 248,793 | 144,171 |

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H. Includes £49 on account of 1948-49 expenditure.
I. Includes £546 on account of 1948-49 expenditure.
J. Includes £2,185 on account of 1948-49 expenditure.
K. Includes £171 on account of 1948-49 expenditure.
L. Includes £194 on account of 1948-49 expenditure.
M. Includes £20 on account of 1948-49 expenditure.

N. Includes £181 on account of 1948-49 expenditure.

### 3. Wool Research Trust Account.

A credit balance of £694,887 was brought forward from 1948-49 in the Wool Research Trust Account. A further £340,970 was received during 1949-50 from the Department of Commerce and Agriculture. Expenditure during 1949-50 was as follows:—

| | Receipts 1949-50 and balances brought forward from 1948-49. | Expenditure 1949-50. | |
|---|---|---|---|
| | £ | £ | £ |
| Division of Animal Health and Production— | | | |
| Sheep Physiology Investigations—Parkville | 2,446 A | | |
| Sheep Physiology Investigations—Tooradin | 2,117 | | |
| Chemical Pathology Investigations—Parkville | 113 | | |
| Toxaemic Jaundice Investigations—Barooga | 314 | | |
| Toxaemic Jaundice Investigations—Cobram | 2,440 | | |
| McMaster Laboratory— | | | |
| Parasitology Investigations | 3,566 | | |
| Parasite Physiology and Toxicology | 817 | | |
| Biochemical Investigations | 2,033 | | |
| Physiology of Reproduction | 673 | | |
| Prospect—Sheep Biology Laboratory | 328 | | |
| Prospect—Sheep Biology Laboratory—Fleece Analysis | 11,935 | | |
| Sheep Biology Laboratory—Wool Biology | 6,431 | | |
| Sheep Biology Laboratory—Strain Trial Investigations | 4,438 | | |
| Co-operative Investigations—Queensland. Wool Production | 110 | | |
| Armidale Regional Laboratory— | | | |
| Parasitology, Agrostology and Field Investigations | 30,148 | | |
| Survey of Wool Production | 3,867 B | | |
| National Field Station, "Gilruth Plains"— | | | |
| Capital | 408 | | |
| Animal Breeding | 2,274 | | |
| Agrostology | 58 | | |
| McMaster Biochemistry Laboratory—Building Alterations | 222 | | |
| | | 74,738 | |
| Division of Plant Industry— | | | |
| Agrostology Investigations | 32,237 | | |
| Mineral Deficiency Studies | 1,701 | | |
| | | 33,938 | |
| Division of Entomology— | | | |
| Cockchafer Grub Investigations | 259 | 259 | |
| Division of Industrial Chemistry— | | | |
| Clover Infertility Investigations | 85 | 85 | |
| Division of Biochemistry and General Nutrition— | | | |
| Biochemical and Nutritional Investigations | 16,645 | | |
| | | 16,645 | |
| Wool Textile Research | 61,308 | | |
| | | 61,308 | |
| Miscellaneous— | | | |
| Overseas Studentships | 9,395 | | |
| Wild Life Survey | 2,619 | | |
| | | 12,014 | |
| | | | 198,987 |
| Grants from Wool Research Trust Account to Institutions undertaking extra-mural co-operative wool research— | | | |
| University of Adelaide—Waite Institute—Agrostology and Onion Weed Investigations | 4,400 | | |
| University of Western Australia—Investigations at Institute of Agriculture, Western Australia | 1,164 | | |
| Department of Agriculture, Western Australia—Sheep Infertility Investigations | 2,000 | | |
| Roseworthy Agricultural College—Progeny Testing and Allied Studies | 2,355 | | |
| Sydney Technical College—Wool Clip Analysis | 2,550 | | |
| University of Queensland—Sheep Physiology Investigations | 750 | | |
| University of Sydney— | | | |
| Animal Physiology and Sheep Infertility Investigations | 2,000 | | |
| Sheep Genetical Studies by Dr. Finlay | 250 | | |
| Department of Agriculture and Stock, Queensland— | | | |
| Progeny Testing and Fertility Investigations | 1,140 | | |
| Georgina River Disease (Poison Plants Committee) | 200 | | |
| Gordon Institute of Technology, Geelong—Wool Textile Investigations | 1,700 | | |
| Wool Industries Research Association, Leeds, U.K.— | | | |
| Wool Textile Investigations | 1,254 | | |
| Extension Work (Professor Hagedoorn) | 596 | | |
| | | 20,359 | |
| Grants from Wool Research Trust Account to Institutions undertaking research in Agricultural Economics relating to wool production— | | | |
| University of Western Australia | 685 | | |
| Roseworthy Agricultural College | 412 | | |
| University of Tasmania | 800 | | |
| Australian Wool Realization Commission | 3,726 | | |
| Department of Commerce and Agriculture—Division of Agricultural Economics | 16,489 | | |
| | | 22,112 | |
| Miscellaneous administrative expenses | 49 | | |
| | | 49 | |
| | | | 42,520 |
| | | | 241,507 |

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A. Includes a credit of £6 on account of 1948-49 expenditure.
B. Includes £236 met on account of 1948-49 expenditure.

### 4. Miscellaneous Services.

| | £ |
|---|---|
| Contribution to Commonwealth Agricultural Bureaux | 20,358 |
| Grant to Standards Association of Australia | 30,000 |
| Grant to Australian National Research Council | 2,000 |
| Contribution to Chair of Aeronautics at Sydney University (establishment and maintenance) | 4,731 |
| Grant to National Association of Testing Authorities | 7,600 |
| | 64,689 |

## XXXVI. ACKNOWLEDGMENTS.

In various sections of this Report reference has been made as in previous years to the valuable assistance afforded by many State Departments, Universities, and other organizations and individuals. The Organization desires to express its gratitude for the help given by these bodies and persons in providing laboratory accommodation and other facilities and in many other ways. The Organization also wishes to acknowledge the assistance it has received from its Committee, the members of which have placed their knowledge and experience so freely at its disposal.

I. CLUNIES ROSS, Chairman
F. W. G. WHITE
S. H. BASTOW
H. J. GOODES
A. B. RITCHIE
Executive.

G. A. Cook, Secretary.
24th November, 1950.

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